

# NAVAL POSTGRADUATE SCHOOL RESEARCH

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## CROSS SECTION OF DISCIPLINES FOCUS ON MISSILE DEFENSE RESEARCH AT NPS

Faculty and students from a cross-section of disciplines at the Naval Postgraduate School have focused research efforts on missile defense over the past several years. This article provides an overview of past and current research in the missile defense arena undertaken by the faculty and students in the Departments of Physics, Mechanical Engineering, Operations Research, Aeronautics and Astronautics, Computer Science, National Security Affairs, Electrical and Computer Engineering, and Systems Management, the Space Systems Academic Group, and the Institute for Joint Warfare Analysis.

### Models and Analysis to Data Analysis: IJWA is Involved in TBMD

Since its inception, the Institute for Joint Warfare Analysis (IJWA) has been active in Theater Missile Defense (TMD). IJWA was founded in 1994 with the mission of addressing the problems of the joint defense arena within the academic disciplines resident at NPS. An early IJWA study under the direction of CAPT George Conner, USN (Ret.) and Distinguished Professor Kneale Marshall (now emeritus), Department of Operations Research, and Associate Professor James Wirtz, Department of National Security Affairs, was aimed at understanding and analyzing the various aspects of attack operations in Theater Ballistic Missile Defense. The final report issued by IJWA combined the faculty's research along with the thesis research of several students in the Operations Analysis Curriculum, LT Mark A. Ehlers, USN (September 1992), LT Thomas W. Hair, USN (March 1993), LCDR Joseph P. Mattis, USN (September 1993), LT Paul A. Soutter, USN (March 1994), LT Vernon L. Junker, USN (March 1995), CAPT Neil E. Fitzpatrick, USA (June 1997), and LT Richard J. Habbelin, Jr., USN (September 1997). The models and analysis contained in the report are all concerned with various aspects of Attack Operations. Attack Operations, attacking the missile launcher system prior to launch, along with Active Defense, shooting down the missile at some point in its trajectory, and Passive Defense, protecting the missiles' intended targets by hardening and other means, comprise the three pillars of TMD.

The primary aspects of the research focused on: 1) Linkages between Theater Missile Defense and Anti-Submarine Warfare; 2) Joint Idea: An ASW Approach to TMD; 3) Quantifying Attack Operations and Active Defense; 4) Searching for Transient Objects Along Roads; 5) Suppression Effects of Searching for TELs; 6) A Pre-Hostilities Decision Model; and 7) Analyses of Unattended Ground Sensors in Theater Ballistic Missile Defense Attack Operations.

IJWA has continued research interest in TBMD and its participation in the data analysis in the Fleet Battle Experiment (FBE) Series provides the opportunity to apply this interest. FBE-Golf (FBE-G) was held in April 2000 in the Sixth U.S. Fleet area of responsibility, the Mediterranean Sea. Real and simulated forces

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# RESEARCH OVERVIEW

## MISSILE DEFENSE RESEARCH, *continued from page 1*

applied network centric operational principles to the Commander, Sixth Fleet (COMSIXTHFLT) critical operational issues. This included building on lessons learned from Operation Allied Force and previous battle experiments. FBE-G featured a decentralized command and control architecture and focused on the protection of time critical targets (TCT) and theater air and missile defense (TAMD), including TBMD.

### Cueing Architecture for Naval Theater Ballistic Missile Defense Program

RADIANT GOLD is the name for an umbrella research and development program under the auspices of the Navy's Tactical Exploitation of National Capabilities (TENCAP) Office (OPNAV N632). One of the many projects under this program is a concept to deliver a space-based cue to the warfighter. The proposed concept is to have the ability to deliver a processed cue from sensor to shooter through a communications network – thereby increasing the effectiveness of the overall TBMD engagement. The dynamic nature of the TBM threat requires rapid dissemination of TBM launch detection and the earliest possible engagement by a TBMD system. RADIANT GOLD disseminates the cue through the most effective means by taking into account the communication capabilities and limitations of current surface combatants and the limited bandwidth available in military satellite communications.

There are several R&D concepts in RADIANT GOLD. First, RADIANT GOLD is seeking out methods and equipment that can improve TBM situation awareness for theater commanders. This can improve operational decisions regarding appropriate passive and active defensive measures and allow the possibility for rapid transition to attack operations for counterstrike. Secondly, RADIANT GOLD is developing methods to cue AEGIS ships of possible TBM events. The use of a cue offers the possibility of a boost/ascent phase detection of a TBM and may lead to an earlier missile engagement. The RADIANT GOLD project is

currently exploring a method, which can satisfy both R&D concepts, by utilizing data derived from a Joint Tactical

Ground Station (JTAGS) ashore. This data can be forwarded to a remote JTAGS (RJTAGS) afloat, instead of waiting for TDDS or TIBS missile alert broadcasts.

As a result of previous experimentation of RADIANT GOLD in theater in August of 1999 aboard the Sixth Fleet's flagship, COMSIXTHFLT requested that the Navy's TENCAP office demonstrate the RJTAGS on an operational surface combatant at sea in conjunction with FBE-G. To this end, TENCAP developed a demonstration plan of RADIANT GOLD's capabilities aboard both the flagship, *USS LaSalle* (AGF-3), and the *USS*

*Mahan* (DDG 72). Each unit was outfitted with an RJTAGS and utilized JBS or EHF communications respectively to receive JTAGS data.

Navy TENCAP established two RADIANT GOLD demonstration objectives within the overall FBE-G objectives. The first objective focused on support to the JTF commander's situational awareness for attack operations and local warning requirements for passive defense. This was to be accomplished by providing national sensor data ashore by a JTAGS to an afloat RJTAGS. The second objective was to provide the same sensor data processed ashore by JTAGS to an AEGIS ship with an active defense mission.

RADIANT GOLD had a successful demonstration while participating in FBE-G. All operational and analytical objectives were met and some insight was gained by TENCAP on the utility of their program. The concept successfully proved that it could send data for not only passive defense, but also active defense and attack operations to users at sea. LT Christopher Atkinson, USN, working with Chair Professors Alan Ross and Charlie Racoosin of the Space Systems Academic Group, explored the RADIANT GOLD concept at the system level and examined it against other

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**The Assistant Chief of Naval Operations (ACNO) for Missile Defense is a newly formed staff function to provide oversight of all policy, planning, budgeting, funding, requirements definition, test and evaluation, deployment, training, operational doctrine, tactics and employment of Naval missile defense systems, including area and theater-wide theater ballistic missile defense (TBMD) as well as overland cruise missile defense. The ACNO for Missile Defense coordinates all missile defense-related programs and initiatives throughout the Navy.**

## RESEARCH OVERVIEW

### MISSILE DEFENSE RESEARCH, *continued from page 2*

methods to distribute TBMD data and its applicability to all TBMD missions, passive and active defense and attack operations.

#### Access Denial

As part of a long-running study of access denial sponsored by the Office of Naval Research and the CNO Executive Panel, Associate Professor **Robert Harney** of the Department of Physics has been examining vulnerabilities of United States forces that could be exploited by an adversary to accomplish denial of access of U. S. power projection forces to areas of the world vital to our national interests. Several "red teams" composed of NPS students and faculty were the instruments used for identifying many of the approaches an adversary might take to access denial. Among the 36 vulnerabilities identified to date, one involves strategic missile defense and another involves tactical ballistic missile defense. In the strategic



**Joint Tactical Ground Station (JTACS), a joint Army/Navy system used to provide theater units with TBMD info.**

sense, the U. S. is vulnerable to any large, prosperous, adversary nation with an ICBM capability. As long as the adver-

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### RADIANT GOLD: AN ALTERNATIVE CUEING ARCHITECTURE FOR NAVAL THEATER BALLISTIC MISSILE PROGRAMS

LT Christopher J. Atkinson, USN  
Master of Science in Space Systems Operations-  
September 2000

Advisors: Alan Ross, Navy Tactical Exploitation of  
National Capabilities (TENCAP) Chair Professor, and  
Charles Racoosin, Naval Space Command Academic Chair

The Theater Ballistic Missile Defense (TBMD) problem is complex and dynamic, requiring the use of space-based sensor system information to enhance mission success. The central purpose of this thesis is to examine the potential of the cueing architecture that results from using a Navy Tactical Exploitation of National Capabilities (TENCAP) sponsored research and development program's concept, termed RADIANT GOLD. The program delivers JTACS processed data derived from national sensor systems to an

AEGIS ship. To this end, this project had three goals. First, model and simulate the cueing architecture under varying degrees of complexity and exploring a diverse set of data dissemination methodologies. Secondly, to examine data derived from a demonstration of the RADIANT GOLD architecture in a recent Fleet Battle Experiment and compare the performance of the architecture to simulation. Lastly, to provide a subjective analysis of RADIANT GOLD and other architectures.

The results from the research indicate that an Extremely High Frequency (EHF) satellite communications network is a suitable method to deliver time critical TBM data. Additionally, the Global Broadcast Service network is an appropriate alternative to EHF. Research also suggests that the RADIANT GOLD architecture is suitable to support the entire spectrum of TBMD operations.

# RESEARCH OVERVIEW

## MISSILE DEFENSE RESEARCH, *continued from page 3*

sary has any capability to strike targets in the U. S. with nuclear missiles, U. S. actions toward that adversary will be different than they would be towards a comparable non-nuclear state. Research is continuing into the degree to which deployment of National Missile Defense systems of varying degrees of ABM treaty compliance would affect this vulnerability, if at all. In the tactical sense, the technical capability exists (even if actual systems are not yet deployed) to target ships at sea with long-range ballistic missiles. Theater missile defense developments have concentrated first on shorter-range (SCUD-like) missiles. Even the most ambitious theater defense systems are limited (by the ABM Treaty) in the kinds of missiles they can engage. Research in this area is focusing on the potential mismatch between projected defensive capabilities and potential offensive capabilities and on how this mismatch might be affected by proposed changes to relevant treaties.

The Total Ship System Engineering (TSSE) Program under the leadership of Professor **Charles Calvano**, Department of Mechanical Engineering, and Robert Harney is a formal partner in the Capabilities of the Navy After Next (CNAN) Study funded jointly by DARPA and the Naval Warfare Development Command. During the six-month long capstone design project, the TSSE student team is investigating the problem of access assurance and defining (in a detailed conceptual design) a new class of small, versatile surface combatants for facilitating access in a network-centric environment. It is envisioned that the survivable, yet expendable “boats” would deploy networks of sensors and weapons throughout the adversary’s access denial zone. Once in place, these assets would ultimately be used to negate the denial systems. One component of the adversary’s denial strategy may well involve the use of terminally guided, longer-range ballistic missiles against our power projection forces once they have entered the denial zone. As a consequence, CNAN is considering the problems and benefits associated with deploying freestanding, canisterized, TBMD assets such as SM-3 missiles deep into the access denial zone. Such forward placement could significantly improve the force protection capabilities of these missiles when compared to basing the missiles on ships of the power projection forces. If the TSSE team concludes that SM-3 forward basing is a significant requirement, then such weapons would be included in the overall mix of sensors and weapons that the CNAN combatants would be required to deploy, and as such would influence the design of those combatants. The TSSE student team is

expected to brief their results in late November 2000.

### Detection and Tracking: Intercepting the TBM in the Atmosphere

For the past three years, Associate Professor **Robert G. Hutchins** and Professor Emeritus **Hal Titus** of the Department of Electrical and Computer Engineering have been engaged in TBMD studies to develop sensor fusion, data association and tracking algorithms to provide the earliest possible detection and tracking information to the interceptor launch site. Hence, they have focused on intercepting the TBM in the atmosphere on the way up. This work has been funded by the Navy TENCAP Office.

The research objective is to develop sensor fusion, data association and tracking algorithms, based on a variety of sensor assets, which will provide the earliest possible detection and tracking information for use in ballistic missile defense. All possible sensors from strategic and theater platforms (space, ship, aircraft, UAV) will be utilized to provide the fastest missile intercept reaction time possible. The aim is to bring to bear all assets available to cover a threatened launch area and to fuse these observations as quickly as they are obtained. This will allow the shooter to launch at the earliest possible time. Rapid ballistic missile launch point prediction is another research objective. Longer-term studies will assess, via simulation, the feasibility of intercepting the ballistic missile during ascent using aerodynamic missiles fired from the surface and/or airborne platforms.

Research has focused on two types of sensors, space based strategic sensors that would likely provide the first indication of a missile launch, and the Aegis radar system as the most likely system to take a hand-off from the strategic sensor to track the TBM until final intercept, although the algorithms developed would allow processing of a much wider variety of sensor types. One issue explored here is how good the initial velocity and acceleration measurements must be in order for the surface-based radar system to take over the target track with a minimum of transient behavior in the track. It was found that prior information on missile velocity and acceleration profiles are extremely helpful in track initiation for the surface-based radar system. Hutchins and Titus have advocated a modified Kalman-based tracking algorithm that allows processing measurements from a wide variety of sensors, provided a common coordinate system framework can be maintained. Both polynomial backfit and Kalman-

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# RESEARCH OVERVIEW

## MISSILE DEFENSE RESEARCH, *continued from page 4*

based backfit strategies for launch point determination have been explored and the Kalman-based strategies have proven superior.

An interactive multiple model (IMM) approach has been developed to boost phase tracking that will track through booster cutoff and even multiple stage booster firings with small errors in the track due to abrupt changes in the missile acceleration profile. Algorithms have been tested using both simulation data and actual theater ballistic missile trajectories representing a variety of third world missiles.

Via simulation, the feasibility of early detection and tracking over North Korea has been studied. These results used actual Aegis radar specifications for single ping and multi-ping target localization. Specific conclusions about the earliest expected detection of a launch, given an alerted ship, were drawn, taking into account both radar horizon and surface terrain.

An aerodynamic missile interceptor based on the Standard missile is currently being modeled. The model includes missile aerodynamics and guidance laws for target intercept. The objective is to assess the feasibility of hitting the TBM during its ascent given early detection and adequate tracking. Testing is planned for various guidance laws, as well as different launch platforms (i.e., ground-launched vs. air-launched interceptor studies).

### Statistical Research in Joint Interoperability Testing of Theater Missile Defense Systems

It is well known that there are substantial technical issues that must be resolved in order to bring a fully workable theater missile defense (TMD) into fruition. Problems of *operability* arise when the components of a single system (e.g. PA-TRIOT) are considered in isolation. Problems of *interoperability* arise when the components of a single TMD system, or multiple systems within the same service branch, are considered as a whole. Problems of *joint interoperability* arise in the context of TMD families of systems (FoS) that are configured to provide coherent engagement, across systems that span service branches, of a theater-area ballistic missile threat. It is the mission of the Joint Interoperability Test Command (JITC) to evaluate, and certify, the joint interoperability of a TMD FoS.

Assistant Professor **Robert Koyak**, Department of Operations Research, has focused research on the development of concepts for measuring the effectiveness and performance of the communication aspects of a TMD FoS. Communication

of potential missile tracks by individual systems to a network participation group follows protocols set forth in military standards. The information that is communicated for a missile track includes position, velocity, estimated launch point, estimated impact point, and error measures for these quantities. Questions being addressed include: 1) Is the information that is communicated timely and accurate? 2) What level of joint interoperability is achievable under current standards? 3) What is needed to improve joint interoperability under a TMD FoS concept?

### Planning the Unthinkable: How New Powers Will Use Chemical, Biological, and Nuclear Weapons

During the summer of 1997, David Altwegg, a senior official in the Navy's Theater Missile Defense program posed several questions to Associate Professor **James Wirtz** and Assistant Professor **Peter Lavoy**, Department of National Security Affairs. Altwegg was concerned about assessing the threat posed by the proliferation of weapons of mass destruction and long-range ballistic missiles, brought about by the limited effectiveness of the Missile Technology Control Regime. Lavoy and Wirtz determined that the most pressing issue faced by Navy officials was to determine what those actors were now planning to do with recently acquired weapons systems. Working with Dr. Scott Sagan, from the Center for Security and Cooperation, Stanford University, Wirtz and Lavoy launched a three-year project to address what former Secretary of Defense William Perry has called "the greatest challenge confronting security policymakers today: understanding the risks of current and future proliferation."

The results of their research, sponsored by the Defense Threat Reduction Agency, the Naval Treaty Implementation Program, USAF Institute of National Security Studies, Navy Theater Air Defense Program, Naval Information Warfare Activity, the Carnegie Corporation and the Smith Richardson Foundation, have recently been published by Cornell University Press. With the help of eight contributors who explored the unconventional weapons programs of Iraq, Iran, Israel, India, Pakistan, North Korea and the Aum Shinrikyo, Lavoy, Sagan, and Wirtz posed several questions. How do states and nonstate groups integrate unconventional weapons into their military infrastructure, delivery systems, command and control procedures, and war plans? What will be the future impact of nuclear, chemical, and biological weapons on regional and international politics? And what does the

*--continued on page 38*

## FEATURED PROJECT

### DETONATION OF A JP-10/AEROSOL FOR PULSE DETONATION APPLICATIONS

Research Assistant Professor Christopher Brophy,  
Department of Aeronautics and Astronautics  
Distinguished Professor David W. Netzer, Department of  
Aeronautics and Astronautics  
Dr. Joseph Sinibaldi, American Society for Engineering  
Education Post-Doctoral Research Associate

The recent interest in Pulse Detonation Engine (PDE) technology has resulted in the initiation of numerous national and international research efforts. Most of these efforts have mainly focused on the detonation of gaseous reactants and continue to produce results for the detonation of fuels such as ethylene and propane. Alternatively, liquid fuels are more desirable than compressed gases because of their higher energy density and considerably better storage properties. In particular, JP-10 is being tested because of its current application in

military weapons and existing approval for shipboard use. Achieving a detonation in a very short length, however, is difficult when using a liquid fuel because of the atomization requirements, mixing time scales, and vaporization of the fuel. Using air as the oxidizer in the main combustor minimizes the need to carry additional oxidizers, thereby leading to a higher density-specific impulse and greater flexibility in the propulsion system design. The possible increase in performance of these systems originates from the increased thermodynamic efficiencies which exist for a detonation process. The research being performed at NPS addresses the practical use of liquid hydrocarbon fuels for pulse detonation applications.

During the past year, researchers at the NPS' Rocket Propulsion and Combustion Laboratory (RPCL) have

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#### About the INVESTIGATORS

Chris Brophy is a Research Assistant Professor in the Department of Aeronautics and Astronautics. He completed his undergraduate and masters degree at Pennsylvania State University and received his Ph.D. from the University of Alabama Huntsville. Dr. Brophy initially joined NPS in 1997 as a Research Associate under the National Research Council Research Associateship Program.



**Chris Brophy**

His teaching and research interests are in the areas of propulsion, combustion, and optical diagnostics. Dr. Brophy is a member of the American Institute of Aeronautics and Astronautics and the American Society of Mechanical Engineers.

David W. Netzer is a Distinguished Professor of Aeronautics and Astronautics and is currently serving as the Associate Provost and Dean of Research. He received the B.S.M.E. from Virginia Polytechnic Institute in 1960, the M.S.M.E. from Purdue University in 1962 and the Ph.D. from Purdue University in 1968. Between the M.S. and Ph.D. he spent two years at the Aerojet-General Corporation as a develop-

ment engineer on the Titan III Transtage Program. He joined the Department of Aeronautics at the Naval Postgraduate School in April 1968 as an Assistant Professor. He was promoted to Associate Professor in 1972, received tenure in 1974, promoted to Full Professor in 1981 and awarded the title of Distinguished Professor in 1994. His teaching and research interests are in combustion and propulsion. In July 1996 he was appointed to the position Associate Provost and Dean of Research.

Dr. Netzer is a member of the American Institute of Aeronautics and Astronautics and The Combustion Institute and is an active participant in the JANNAF Combustion and Exhaust Plume Technology subcommittees. He is a member of Sigma Xi, Pi Tau Sigma and Tau Beta Pi and has received the SAE Ralph R. Teetor Education Fund Award, the Admiral J.J. Schiefflin and Allen Griffen awards for excellence in teaching and the JANNAF Combustion Subcommittee



**David W. Netzer**

Annual Award. He has published 40 articles in journals and books, over 40 papers in proceedings and over 40 technical reports and co-edited the recent AIAA volume on Tactical Missile Propulsion.

## FEATURED PROJECT

### JP-10/AEROSOL FOR PULSE DETONATION APPLICATIONS, *continued from page 6*

successfully detonated a JP-10/air aerosol in a PDE combustor. Previous research at the laboratory resulted in the first two-phase detonation of a JP10/oxygen mixture and recent efforts resulted in the first documented two-phase detonation of JP-10 and air. The results demonstrate the practicality of liquid-fuel detonations for PDE applications.

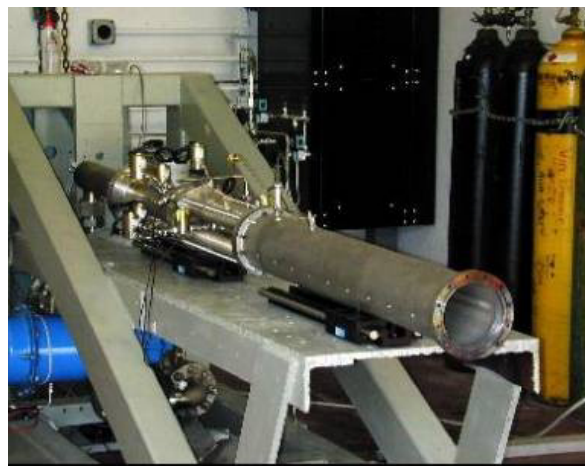
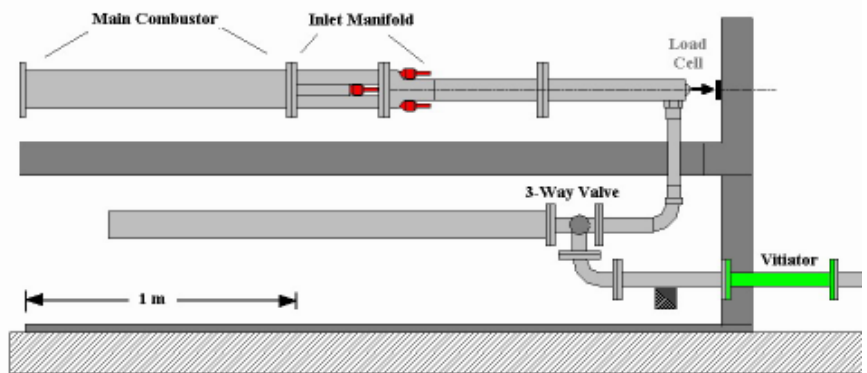
Due to the nature of the combustion process, the mode of operation for a typical PDE is cyclical. The fuel/air mixture is loaded into a combustor, rapidly detonated, and then the products are exhausted. The resulting pressure behind the detonation wave presses on the head-end, or thrust wall, of the combustor to generate thrust. After the combustion event is complete, the exhaust is expelled from the combustor and a new fuel/air mixture is loaded and the procedure repeats. This repeated fill/detonate/exhaust process typically must occur at frequencies of 40 Hz or greater to generate a reasonable thrust level for most systems.

Gaseous systems possess an inherent simplicity since all of the fuel is already in a vapor state and is therefore more likely to react rapidly with the oxidizer, which is required in a detonation wave. Generally, the energy release must occur within 1cm of the detonation leading shock. If the heat release occurs too late, the combustion zone decouples from the shock and the detonation will likely fail. In a two-phase condition, such as a JP-10/air aerosol, the fuel must be significantly vaporized before a substantial reaction can occur. Calculations indicated that a spray possessing droplets below 6 microns in diameter would be required to support a two-phase detonation wave.

The experimental facility used for this work, shown in Figures 1 and 2, was operated at air flow rates of up to 1.3 kg/s (3 lbm/s) and provided the engine with air inlet temperatures of up to 500 K. The air was heated by a hydrogen vitiator with make-up oxygen and a maximum outlet temperature of 725 K. The vitiator outlet was connected to the engine inlet through a 6.35 cm (2.5 inch) diameter flex hose. The engine geometry is shown in Figure 3 with exploded views of selected areas. The engine inlet choke isolated the vitiator from pressure oscillations in the main combustor and

allowed for redundant metering of the vitiated air flow. Fuel was injected just after the inlet choke and was allowed to mix completely before being discharged into a plenum region and then injected into the main combustor through a perforated cone segment in order to provide increased turbulence, mixing, and partial acoustic isolation.

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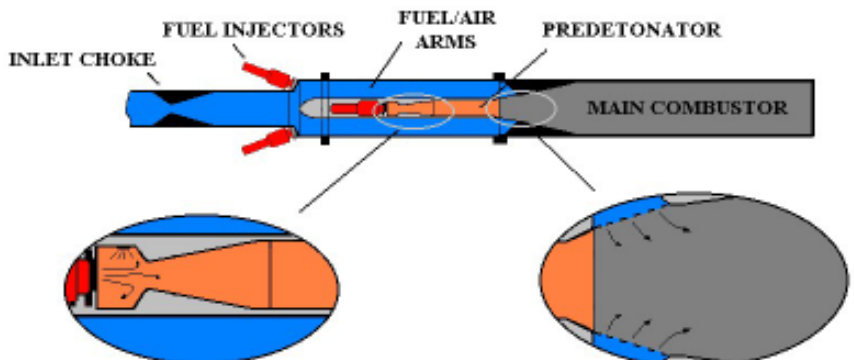


From top to bottom:

Figure 1. Experimental Layout

Figure 2. Test Cell View of Experimental Setup

Figure 3. Pulse Detonation Engine Geometry



## FEATURED PROJECT

### MICRO-AIR VEHICLE AERODYNAMICS - AN EXCITING NEW FRONTIER IN AERODYNAMICS

#### Investigators:

Distinguished Professor Max F. Platzer, Department of Aeronautics and Astronautics

Research Assistant Professor Kevin D. Jones, Department of Aeronautics and Astronautics

#### Past Research Associates:

Dr. Joseph Lai, Associate Professor, Australian Defense Force Academy, Canberra, Australia

Dr. Ismail Tuncer, Associate Professor, Middle Eastern Technical University, Ankara, Turkey

#### Present Students:

Captain Breno Castro, Ph.D. Student, Brazilian Air Force

Major Osama Mahmoud, Ph.D. Student, Egyptian Army

#### Recent Past Students:

Commander Claus Dohring, German Navy

Captain Scott Davids, USMC

Lieutenant Timothy Lund, USN

Captain Sean Duggan, Canadian Armed Forces

In the past, most flight problems of interest to aeronautical engineers involved flight at high Reynolds numbers - say one hundred thousand or higher (the Reynolds number compares

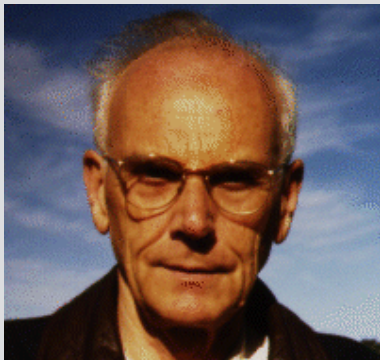
the magnitude of the fluid particle's inertia force with the viscous force acting on the particle). However, four years ago the Defense Advanced Research Projects Agency (DARPA) issued a requirement for the development of micro-air vehicles (MAVs) which are no larger than six inches in length, span or height. As a consequence, a new Reynolds number regime is becoming of importance for the design of such vehicles where very little reliable aerodynamic design information is currently available. As a matter of fact, the most efficient ways of generating lift and of minimizing drag are still to be explored.

Birds and aquatic animals have evolved various means of propulsion and lift generation. However, the low commercial and military interest in micro-air vehicles has delayed the development of aerodynamic theories and experimental data for flight in the very low Reynolds number regime. It appears that the DARPA initiative is opening up an exciting new frontier in aeronautical engineering. Of special interest is the study of flapping wings for thrust and lift generation which is used so successfully by birds, insects and aquatic animals. For the past several years, we have been pursuing experimental

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### About the INVESTIGATORS

Maximilian F. Platzer is a Distinguished Professor in the Department of Aeronautics and Astronautics. He received his formal education, Diploma Engineer, B.S., and Ph.D.



**Maximilian F. Platzer**

from the Technical University of Vienna, Austria. Before joining NPS, Dr. Platzer worked at Lockheed-Georgia Research Laboratory and the NASA Marshall Space Flight Center.

His teaching interests are in the areas of aerodynamics, aeroelasticity, and flight

mechanics. His research has focused on aeroelasticity, flight mechanics, and flight propulsion. He is a Fellow of the American Institute of Aeronautics and Astronautics and the American Society of Mechanical Engineers, and serves on

the editorial board of *Progress in Aerospace Sciences*.

Kevin D. Jones is a Research Assistant Professor in the Department of Aeronautics and Astronautics. He received his B.S., M.S., and Ph.D. from the University of Colorado. Dr. Jones initially joined NPS as a Research Associate under the National Research Council Research Associateship Program.

His research interests include unsteady aerodynamics and aeroelastic computations. He has developed graphical user interface (GUI) software for aerospace applications and web-based aerospace applications such as the NPS Online Panel Code and the NPS Online Transonic Small Disturbance Flow Solver.



**Kevin D. Jones**

## FEATURED PROJECT

### MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 8*

and computational studies of flapping-wing propulsion. It is the purpose of this article to provide a review of the current status of our work. We start by first describing the two test facilities which are used for the experimental studies, namely a low-speed wind tunnel and a water tunnel.

#### The Aeronautics Low-Speed (Smoke) Tunnel

The low-speed wind tunnel, sometimes referred to as the smoke tunnel, is a continuous, flow-through facility, with a five-foot by five-foot test section. The tunnel, depicted in Figure 1, has a speed range from zero to about 10 meters/second (~22.5 mph). The relatively low speed makes it particularly suitable for flow visualization investigation where smoke, fog or other visualization techniques are required, and this is also the speed range of interest for micro-air vehicles. The tunnel is driven by a constant-speed motor with a variable pitch fan, changing the pitch of the fan to control the wind-speed.

The tunnel is equipped with a positionable pitot-static tube and several high-accuracy differential pressure transducers for wind-speed measurement, as well as a 2-component Laser-Doppler Velocimetry (LDV) probe for measuring unsteady, local flow speeds with high accuracy. LDV is a non-intrusive method of measuring fluid velocity by optical means. Our system uses a water-cooled 5 Watt Coherent Innova 70C CW Argon-Ion Laser for a light source. The Coherent laser emits

several discrete colors (green - 514.5nm, blue - 488nm and purple 476nm), and a TSI Model 9201 ColorBurst multicolor beam separator is used to split the beams and frequency-shift one beam in each color. The green and blue beams, and their frequency shifted counterparts, are passed to a 2-component, 4-beam TSI Model 9832 probe through a fiber-optic cord. Probe beam spacing is 50mm, and lenses with focal lengths of 350mm and 750mm are available. Several methods are available for flow visualization. A Roscoe 4500 fog machine is attached to a smoke rake which is placed outside the tunnel intake, and this provides sufficient flow-seeding for the LDV measurements as well as flow visualization at higher tunnel speeds. A smoke-wire may be used to generate a sheet of smoke inside the test-section, a useful technique at lower tunnel speeds, as shown in Figure 3. Additionally, a laser light-sheet may be used with the Coherent laser, providing a bright, two-dimensional slice through the seeded flowfield.

#### The Eidetics Water Tunnel

We also have an Eidetics water tunnel, shown schematically in Figure 2, an ideal tool for flow visualization. The tunnel has a speed range between 0 and about 0.5 m/s, with a usable test section that is about 38cm square. It is a continuous flow tunnel with a 6:1 contraction ratio.

Flow visualization is performed by injecting dye into the water. Multiple colors of dye can be used to identify different

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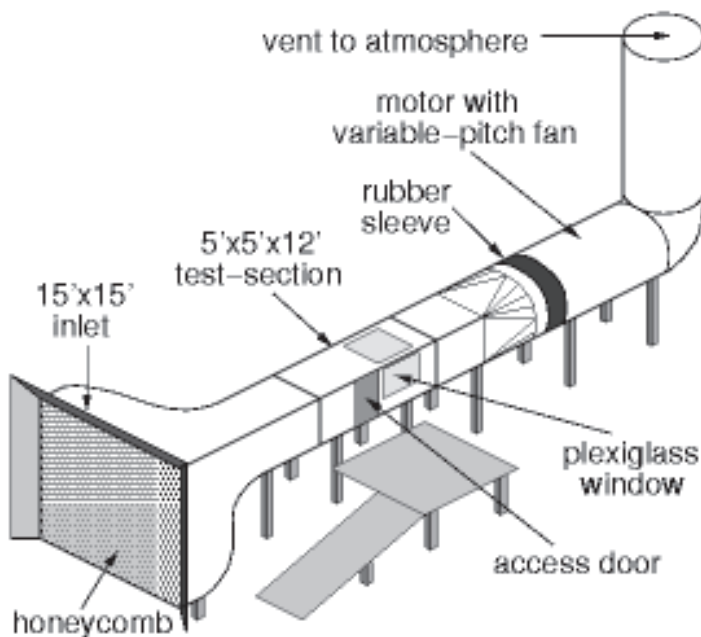


Figure 1. Schematic of the low-speed wind tunnel.

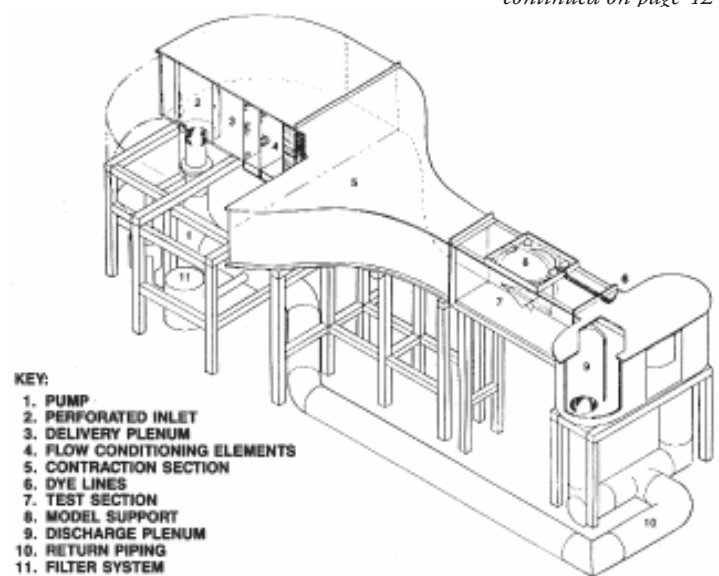


Figure 2. Schematic of the Eidetics water tunnel.

## WEAPONNEERING: FROM A JTCG/ME PERSPECTIVE

### Introduction

In general terms, weaponneering can be defined as the process of determining the quantity of a specific type of weapon required to achieve a specific level of target damage, considering target vulnerability, weapon effects, munition delivery errors, damage criteria, probability of kill, weapon reliability, etc. In the operational arena, where planners are striving for the most effective use of limited resources, efficiency is a critical factor that must be considered in the weaponneering process. Commanders want to use their weapons systems to inflict maximum damage on enemy plans, forces, and facilities. Under these conditions *weaponneering* is probably best defined as the process of determining the minimum-force level and optimum ordnance needed to achieve a desired level of damage to a target or critical component, such that enemy warfighting is affected.

### History of the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)

In 1963, an Army-Air Force panel known as the Close Air Support Board issued a report calling attention to large gaps and gross inaccuracies in data then published on air-to-surface non-nuclear munitions. To remedy these inconsistencies, the board recommended production of a joint service publication containing a comprehensive list of targets with corresponding data on the effectiveness of aerially delivered munitions suitable for defeating those targets. Responding to this challenge, the Joint Chiefs of Staff requested that a joint service working group correct the data deficiencies and prepare a Joint Munitions Effectiveness Manual (JMEM) for air-to-surface weapons. The Army was tasked to be the lead service. The Chairman of the JTCG/ME established an ad hoc group of military and civilian scientists scattered through the Defense Department. The group developed the first standardized methodology for evaluating weapons, and this product was a coordination draft of a multi-service manual entitled *Joint Munitions Effectiveness Manual for Air-Delivered Non-nuclear Weapons*. This manual was accepted not only by the scientists and military professionals but also by the Secretary of Defense. The latter requested that a similar approach be applied to surface-to-surface weapons.

In the fall of 1965 the original ad hoc group was given formal status as the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME) by the Joint Logistics Commanders. By mid-1966, the JTCG/ME was supported by three working groups: Target Vulnerability, Chemical and

Biological, and the original Air-to-Surface (JMEM/AS) Group. These working groups, in turn, controlled the activities of subgroups created and tailored for specific aspects of the parent group's mission. The JMEM/AS had subgroups for weapon characteristics, delivery accuracy, flame and incendiary effects, methodology, and publications. A separate Basic Manual Working Group, chaired by the Defense Intelligence Agency, was established to maintain the *Weapon Effectiveness, Selection, and Requirements - Basic JMEM/AS Manual*. In January 1967, JTCG/ME brought in a JMEM Production Contractor to provide support for the development and production of technical handbooks, JMEMs, special reports, and related publications.

By 1967, the JTCG/ME was concerned not only with deriving or validating data by tests, experiments, and mathematical models, but also from direct inputs of data from the battlefield. The JTCG/ME Wound Data and Munitions Effectiveness Team gathered wound data from Southeast Asia (SEA). Later, the team expanded the scope of its battlefield collection to include materiel and sent specialized teams to SEA under an effort labeled BDARP-Battle Damage Assessment and Reporting Program. These data are currently stored in the Survivability/Vulnerability Information Analysis Center (SURVIAC) at Wright-Patterson AFB and are available for study and research by DoD agencies and contractors.

In September 1967, a separate major group, JMEM/SS, was created to examine and produce data on surface-to-surface munitions. Manuals containing data on individual surface-to-surface weapons were published and revised as new targets or munitions were developed. To complete the weapon-target interface the JTCG/ME established the Anti-Air Working Group in 1976. Additionally, a Red-on-Blue Working Group was formed in 1977 to address the effectiveness of Red munitions on Blue targets. A Special Operations Working Group, initiated in 1983, provided target vulnerability and weapon effectiveness studies for Special Forces. In 1994, the JTCG/ME was reorganized with four major working groups: Air-to-Surface, Surface-to-Surface, Anti-Air, and Vulnerability (including Special Operations) to cover the spectrum of weapon effects issues. In addition, each working group is supported by a formally chartered Operational Users Working Group (OUWG). The Central Office is the focal point for all JTCG/ME efforts. They coordinate the efforts of the working groups while the execution of those efforts is the responsibility of the working group chairmen.

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## WEAPONEERING: FROM A JTCG/ME PERSPECTIVE, *continued from page 10*

In May 1999, the Office of the Secretary of Defense (OSD) revised DoD Directive 5000.2R to require the procuring agency to provide weapon effectiveness data for use in JMEMs for weapons in the acquisition process prior to their achieving initial operational capability. OSD also required that these data be prepared using methodology coordinated with the JTCG/ME.

The resources to operate the program are distributed to the JTCG/ME directly from the Director of Operational Test and Evaluation, Office of the Secretary of Defense. Chartered by the Joint Logistics Commanders with two-star or civilian-equivalent Offices of Primary Responsibility (OPR), the JTCG/ME is guided by a steering committee composed of members from each of the services, the Joint Chiefs of Staff (J-8), the Defense Intelligence Agency, and the Defense Threat Reduction Agency. The Army continues as DoD Executive Agent, as it had been with the original ad hoc group, and the Director of the U.S. Army Materiel Systems Analysis Activity at the Aberdeen Proving Ground, Maryland, presides. The committee is composed of civilian and military weapon/munitions experts throughout the defense department to ensure objective, scientific guidance in the development and employment of non-nuclear munitions. An organizational chart is shown in Figure 1.

### NPS Involvement With the JTCG/ME

About six years ago, Professor Morris Driels of the Depart-

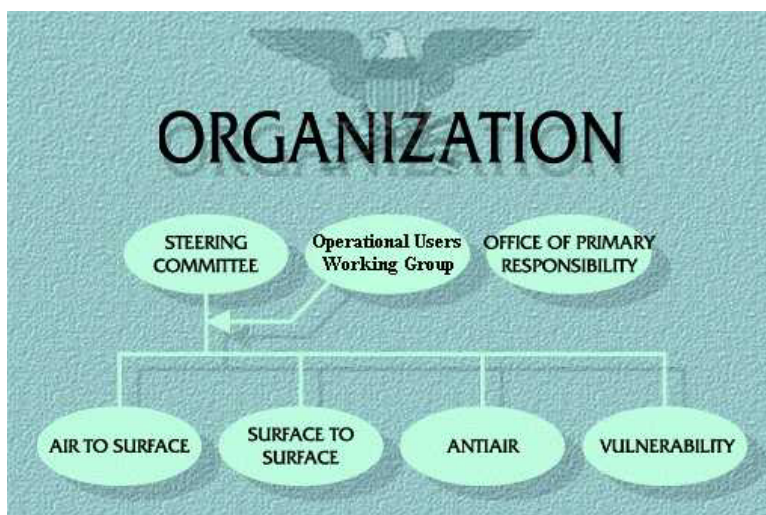


Figure 1. Organization of the JTCG/ME.

ment of Mechanical Engineering was interested in pursuing a new direction in his research activities, branching away from the more traditional Mechanical Engineering subject matter he had been working with at several universities for over twenty five years. He had learned of the JTCG through a colleague in the Operations Research Department at NPS, and they began work on a project that predicted the probability that ground targets could be detected, recognized and identified from the air. By this time, the Air-to-Surface Working Group -ASWG (Figure 1) based at Eglin AFB was consolidating its products into a CD-ROM and away from the traditional orange covered paper JMEMs that users were familiar with since the inception of the group. This product, known as the Joint Air-to-Surface Weaponneering System, or JAWS, is the focal point of all Air-to-Surface (AS) activities, and although not a strict part of weaponneering, the Target Acquisition program developed at NPS was incorporated into it in 1998. A sample screen is shown in Figure 2, and indicates the probability a target may be detected as a function of altitude, terrain masking, target size and contrast, and other factors.

Following this work, Professor Driels became involved in the analysis of the delivery accuracy of weapons, particularly that of the AGM-65 Maverick missile and the GBU 31/32 JDAM guided bomb. He was also vaguely aware of the other components of weaponneering that others were working on, and needed to be done

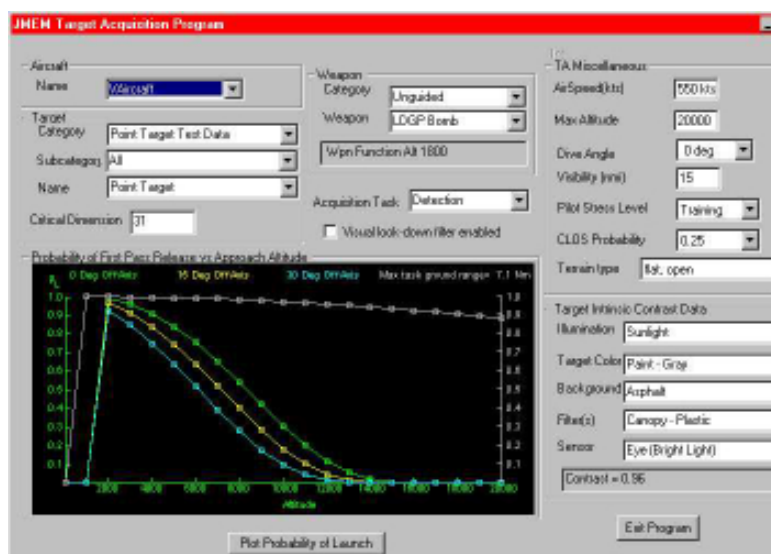


Figure 2. Target Acquisition Program in JAWS.

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## WEAPONNEERING: FROM A JTCG/ME PERSPECTIVE, *continued from page 11*

each time a new weapon system or delivery platform was fielded. These areas included weapon effects, delivery tactics, weapon trajectory, target vulnerability, and methodology development to tie them all together.

Professor Driels began to investigate how all of these various components were linked, and how the output from one would provide input to another. Of course the work had been ongoing for at least 30 years, but the surprising observation was that there are few people, if any, who have a good overview of all the components comprising weaponneering. In Driels' estimation, there may be at most five such people. There is no textbook on the subject, and no courses at an analytical level are available. All of the analysis and methodologies are to be found in DoD reports, manuals, contractor documents, hand-written notes and in some cases by examination of the JAWS source code.

It occurred to Driels that once the five or so people who know how it all works were gone (at least 3 are at or near retirement age) all collective knowledge of the subject would

disappear. This will be a major problem when substantial enhancements to the product requires a reality check with what has been done before, and to ensure the wheel is not invented yet again.

With this in mind, Driels began to write his own notes on the subject of weaponneering, using a common notation and approach consistent with all the material he had gathered. The work focussed on air-to-surface engagements, since this is the area he was most familiar with, although the work is easily extended to the surface-to-surface arena. This material was then verified by the individual subject specialists to assure correctness. Although the work was done with JTCG sponsorship, it seemed that one way to see if all the material formed a unified and consistent subject would be to teach a course in weaponneering at NPS, and such a course was offered for the first time in the Summer of 2000.

In essence, the course explains and develops the various methodologies that underpin the JAWS product, and explain

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## ME4300 WEAPONNEERING – COURSE SYLLABUS

### PART 1 – BASIC TOOLS AND METHODS

#### 1. Weaponneering as part of the targeting process

- 1.1 Definitions
- 1.2 Weaponneering-part of a larger planning cycle
- 1.3 Process sequence
- 1.4 How to weaponneer

#### 2. Elementary Statistical Methods

- 2.1 Univariate distribution
- 2.2 Univariate normal distribution
- 2.3 Bivariate normal distributions
- 2.4 Circular normal and Rayleigh distributions
- 2.5 Binomial distributions
- 2.6 Poisson distributions
- 2.7 Testing data for a particular distribution
- 2.8 Functions of random variables

#### 3. Delivery Accuracy

- 3.1 Introduction to delivery accuracy
- 3.2 General measures of delivery accuracy
- 3.3 Commonly used equations based on normal data
- 3.4 Delivery accuracy data in the normal plane
- 3.5 Treatment of ballistic errors
- 3.6 Delivery accuracy of unguided weapons
- 3.7 Generalized bombing problem
- 3.8 Application to continuously computed impact point (CCIP) mechanization

- 3.9 Example mode for CCIP mechanization
- 3.10 Additional error source and error budget approach
- 3.11 Application to continuously computed release point (CCRP) mechanization
- 3.12 Example mode for CCRP mechanization
- 3.13 Bombing on coordinates mechanization
- 3.14 ADAM – An air-to-surface delivery accuracy model
- 3.15 Guided weapon delivery accuracy

#### 4. Vulnerability Assessment – Introductory Methods

- 4.1 Introduction
- 4.2 Requirements for the computation of effectiveness indices
- 4.3 Vulnerability assessment for fragmentation warheads
- 4.4 Vulnerable area
- 4.5 Critical and non-critical components
- 4.6 Redundant and non-redundant components
- 4.7 Target vulnerability to single fragments
- 4.8 Case(a)–Target composed of non-redundant components with no overlap
- 4.9 Case b)–Target composed of non-redundant components with overlap
- 4.10 Case(c)–Target composed of some redundant components with no overlap
- 4.11 Case(d)–Target composed of some redundant components with overlap
- 4.12 Multiple hit vulnerability

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# RESEARCH AND EDUCATION

## WEAPONNEERING: FROM A JTCG/ME PERSPECTIVE, *continued from page 12*

from an analyst's point of view how the basic Single Sortie Probability of Damage (SSPD) is computed for various weapon/target combinations. An example of one such scenario is shown in Figure 3, and is a screen from an unclassified version of a weaponneering program similar to JAWS.

The course is classified as SECRET, not because of the classroom material, but because it was expected that discussion of first hand experiences by the students would quickly get to the classified level, and this has proven to be the case.

In the first class there were 13 students representing a very broad range of backgrounds for such a small group. There were 5 curricula represented (Operations Analysis, Combat Systems Sciences and Technology, Naval/Mechanical Engineering, Aeronautical Engineering, and the NPS/Test Pilot School Cooperative Program), representatives from the Navy, Army and Marine Corps, USN surface and submarine communities, and aviators from FA-18, FA-14, AV-8B, A-6 aircraft and H60 helicopters, and a Marine M1A1 tanker.

There is no textbook available, but Professor Driels has prepared

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Figure 3. Example of Weaponneering Program.

## ME4300 WEAPONNEERING – COURSE SYLLABUS, *continued from page 12*

- 4.13 Effectiveness assessment for a specific weapon
- 4.14 Calculation of lethal area

- 6.6 High fidelity models
- 6.7 Trajectory for LGB's and missiles

### 5. Vulnerability Assessment – Advanced Methods

- 5.1 Introduction
- 5.2 Computation of vulnerable area – COVART
- 5.1 COVART shotline analysis
- 5.2 COVART shotline  $P_{k/h}$  program
- 5.3 Output of COVART program
- 5.4 General full spray model – GFSM
- 5.5 Orientation of weapon in GFSM scenario
- 5.6 GFSM target description
- 5.7 GFSM weapon description
- 5.8 GFSM fragment drag data
- 5.9 Computational model
- 5.10 GFSM computation of  $P_{k/h}$
- 5.11 GFSM computation of  $P_{k/h}(r,g)$ 's
- 5.12 Review of computational procedure
- 5.13 Computation of  $P_{k/h}$  matrix
- 5.14 Simplification of lethal area for weaponneering
- 5.15 Damage function for targets sensitive to blast

### 6. Weapon Trajectory

- 6.1 Introduction
- 6.2 Weapon delivery tactics
- 6.3 Initial release velocities
- 6.4 Zero-drag point mass model
- 6.5 Linear drag model

### 7. Weapon selection

- 2.1 Aircraft weapons
- 2.2 Selecting the weapon for the target

## PART 2 – THE WEAPONNEERING PROCESS

### 8. Single weapons directed against point targets

- 8.1 Introduction to single sortie probability of damage (SSPD)
- 8.2 SSPD's using the Carlton damage function
- 8.3 SSPD's for unitary blast damage function and point target
- 8.4 Some computational considerations
- 8.5 Force estimation
- 8.6 Simple spreadsheet implementation to compute SSPD's
- 8.7 Spreadsheet template for implementing weaponneering solutions
- 8.8 Calculating SSPD's for guided weapons

### 9. Single weapons against area targets

- 9.1 Effect of area target on SSPD calculation
- 9.2 Target larger than the damage function

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### WILL RAD-HARD SEMICONDUCTOR CHIPS FOR MILITARY AND SPACE APPLICATIONS BECOME A THING OF THE PAST?

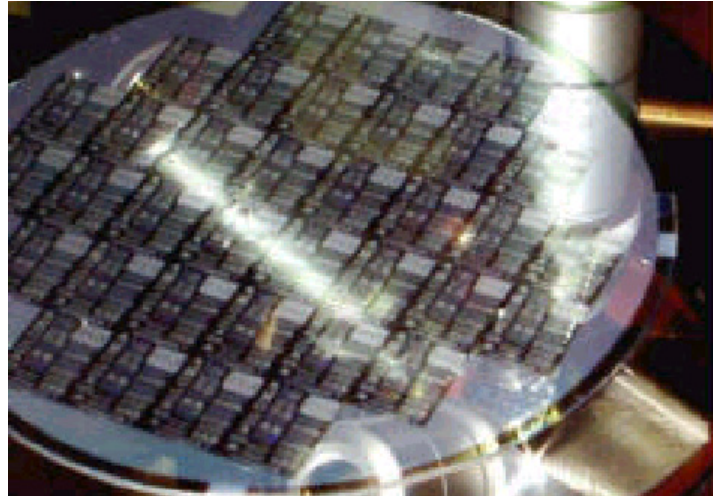
#### Background

Over the last decade, even though the semiconductor industry has grown into the most influential industry for our technological revolution, our capability to develop electronics capable of operating in radiation environments is slowly disappearing. One would first think that reduced DoD budgets after the Cold War would be the obvious reason for this, however economic and technical issues have contributed to the problem.

#### Economical/Cold War Factors

In the 1980s over 30 vendors for high reliability/radiation hardened semiconductor products existed. Today only three exist, Honeywell, Intersil, and Loral, which build integrated circuits (IC) for the harshest radiation environments, strategic weapons, and space. The fear is that these three may vanish in the future. The semiconductor business is very profitable because approximately every 18 months, engineers increase the performance by 4X and increase the number of chips by 30% on each 8" silicon wafer. This is only possible due to enormous volumes of fabricated wafers that allow tight processing control to yield large percentage of functioning "chips." The adage, "Practice makes Perfect" fits well with this industry, where 10 million, sub-micron size transistors exist to a single chip, where 100s of chips are on each wafer and the average semiconductor firm can fabricate 5,000 to 50,000 wafers a week. Consumer demand has fed this revolution and this trend will clearly continue, to the best of our knowledge to well after 2015. However, the needs for all commercial space, military space, and strategic systems would be lucky to require 5,000 wafers in a year (less than 0.1% of the industry). Due to this relatively low customer demand for rad-hard ICs, and high-required throughput to statistically output a reliable product, the price of a state-of-the-art (SOTA) semi-rad-hard single board computer in 1999 was \$60K for a 486 chip set running at 60 MHz. A 120 MHz Pentium II chip set is expected out soon for \$100K. Present rad-hard ICs are 3-4 generations behind the commercial SOTA and at 100 times the cost. The gap in performance will become even larger in the future. Essentially to build a relative low volume of reliable chips (i.e. integrated circuits, ICs) above and beyond the average Commercial-off-the-shelf (COTS) IC, we are limited to how much we can "practice."

The odd fate to DoD is that in the 60s and 70s the majority of semiconductor chips were built for the Defense Depart-



**Integrated circuits fabricated by Vitesse Semiconductor (Camarillo, CA) on an epitaxial GaAs semiconductor wafer developed by NPS researchers. The NPS wafer utilizes a layer of "electron trapping sites" to make the circuits immune to radiation effects.**

ment, and being the major customer of the industry, the DoD required rigid specifications on how vendors were to build semiconductor chips. DoD's specifications which required high reliability, and radiation hardness eventually could not be met by the exploding demand for less reliable commercial products, thus vendors moved away from DoD applications. Today DoE and DoD have small fabrication facilities at Sandia and SPAWAR, however they are not to compete with industry, and are limited in capital expenditures to keep pace with the commercial rad-hard vendors.

Since the end of the Cold War and the reduction of rad-hard IC manufacturing, very few experts are left in the radiation effects community. The national laboratories held many of the researchers, however most of these "graybeards" have retired. Potential students are drawn to high paying positions in Silicon Valley firms. As for university research, only a couple of programs exist which study radiation effects. Those universities which do have expertise in rad effects have a difficult time finding graduate students cleared for classified or sensitive military programs.

In recent years, several DoD strategic programs (Trident and Minuteman) are in the stages to redesign their electronic systems. Many of the original 1960 to 1970 vintage ICs are no longer available. Very few recent rad-hard or commercial

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## RAD-HARD SEMICONDUCTOR CHIPS, *continued from page 14*

components have been tested for strategic radiation levels. Additionally several of the newer programs, National Missile Defense (NMD) and TBM and many of the surveillance programs require radiation hardened-components. Further underground tests have been eliminated and many of the radiation testing facilities for weapons effects have been taken out of service.

### Technical Issues

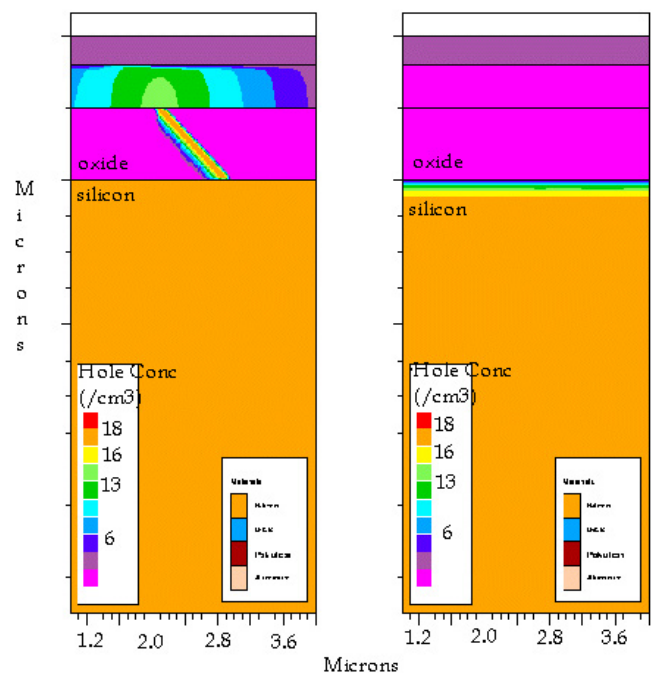
Each successive generation of transistors shrinks in size. Ten years ago each individual transistor “pushed” about 5-10 million electrons from circuit node to circuit node. Today, the average transistor switches about 100,000 electrons. In the next 5 years or fewer, it will be 1,000 electrons. Cosmic particles from space or byproducts of radioactive isotopes in everyday materials interact with transistors and ionize millions of electrons. These “single particle” events are known as “soft errors” which randomly turn transistors on or off causing computer programs to fail. The density of cosmic particles at the earth’s surface is much less than in space (approximately 10 cosmic particles pass through your body a day), however many more low energy particles exist than high energy ones at sea level, thus as each new generation is released the ICs become more susceptible to natural radiation. Before 1979, the relatively “large” transistors showed no susceptibility for single particle radiation anomalies, but each following generation has shown more problems. Unknown to most, at 50,000 feet in the upper atmosphere a neutron cloud is produced from cosmic particle interaction. In the last two decades integrated circuits in avionics, and in computer systems at high elevations have shown increased susceptibility to natural radiation. Much closer to everyone’s desktop, in the last two years IBM and INTEL have had to switch completely to alpha particle-free solder due to prevent upsets from decaying isotopes in the lead solder. Studying the present roadmap for semiconductors, almost all ICs will become susceptible in the next decade to “natural” radiation. Imagine the difficulty for space and strategic system engineers to design for harsher radiation environments.

In oxides, ionized electrons can get “trapped” in the insulator and over years (in space applications) or nanoseconds (weapons applications), charge builds up interfering with the transistor operation. This “total dose” of radiation to initiate failure is known as Total Dose and is in units of Rads( $10^{-7}$  J/gm). Rad-hard ICs are designed with special oxides that can withstand Megarads. Commercial ICs at best can survive to

20K Rads. One recent worry from DSWA (Defense Special Weapon Agency) is that a rogue nation could launch one small nuclear weapon into the upper atmosphere, which could produce sufficient ionizing radiation to pump up the Van Allen radiation belts from underneath and engulf many of the Low Earth Orbit (LEO) satellites in radiation. Almost all commercial satellites at LEO utilize unhardened commercial parts. Such an event would cause hundreds of satellites to fail due to Total Dose effects within 30-60 days and this expanded radiation belt would last on the order of a year. Previous U.S. and Soviet upper atmosphere nuclear tests in the 50s and 60s reeked havoc on early satellite systems. Today’s semiconductor chips in some respects are more vulnerable, with many more satellites at stake.

The same particles that can ionize electrons, with more energy these particles can displace atoms in a semiconductor crystal or in insulating oxides. Each displacement of an atom introduces a charged point defect, essentially an atom out of place in the crystal. In the near future, the capability of a single particles displacing one Oxygen or one Si atom in a six-to-eight atom thick Silicon Dioxide layer would permanently damage the transistor.

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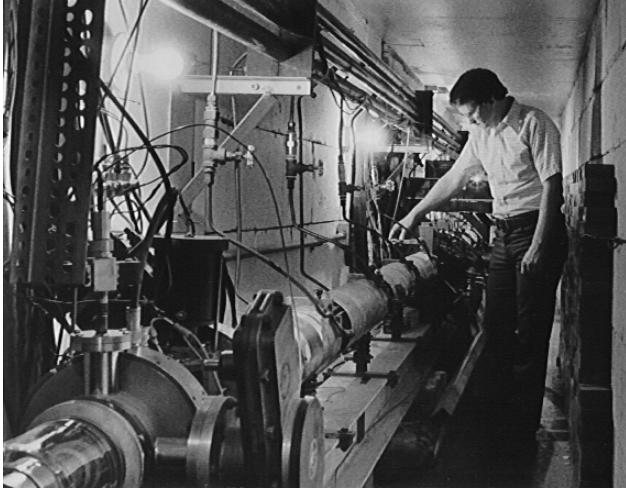
**An example of a two-dimensional simulation of a cosmic particle ionizing charge in a MOSFET transistor. The simulation code allows researchers to track how ionized charge moves through a semiconductor structure.**

# RESEARCH CENTER

## RAD-HARD SEMICONDUCTOR CHIPS, *continued from page 15*

### Creation of a Center of Excellence at NPS

Because of the importance of rad-hard electronics to both the defense and commercial sector the organization of a center of excellence at NPS has a unique ability and advantages in this field: a) Several faculty who research radiation effects in electronics, b) Unique radiation sources (NPS LINAC and Flash X-ray facility), 3) Graduate students cleared at the secret and top secret level, 4) Close



**Electronics Technician Don Snyder in the early 1970s maintaining the LINAC beamline. Thirty years later, Don Snyder was critical in revitalizing the LINAC after damage due to flooding in 1998.**

proximity to Silicon Valley to interact with semiconductor

foundry and virtual fab software firms, and 5) Close interaction with DoD personnel in R&D, acquisition, and operations that require rad-hard ICs.

For several years, projects related to radiation effects have been increasing at NPS and the idea of a center has been discussed. Recently the NPS Linear Accelerator (LINAC) and the Flash X-ray facility have been revitalized. These facilities are now available for faculty to supplement research and for outside researchers needing radiation sources.

The faculty at NPS has a broad range in studying radiation effects in electronics; Associate Professor **Sherif Michael**, Department of Electrical and Computer Engineering, has done considerable work in studying solar cells and analog electronics, Associate Professor **Douglas Fouts**, Department of Electrical and Computer Engineering, in the design and layout of rad-hard digital VLSI circuits, and

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**The members of the new Center for Radiation Hardened Effects and others at NPS would like to thank both Electronics Technician Don Snyder, Department of Physics, and Professor Emeritus Fred Buskirk in providing an exceptional effort to bring the LINAC back to operation.**

## HISTORY OF NPS' LINEAR ACCELERATOR: THE "LINAC"

In the early 1960s, **Franz Bumiller** joined the NPS faculty after several years of research at the Stanford High Energy Physics Laboratory. He wanted to build a linear accelerator at NPS that would be smaller than the Stanford accelerator. Work was started in January 1965 and a beam was obtained in 1967. NPS Physics Professors **John Dyer** and **Fred Buskirk** were involved in this early phase of the NPS LINAC.

The initial construction was funded by a \$250,000 grant from the Chief of Naval Research. Also much excess equipment was obtained from Stanford laboratories. Material obtained from Stanford included the accelerator beam pipes, electromagnets to handle the beam and some of the electronic instrumentation. In addition, much DoD surplus was obtained, including about 100,000 pounds of lead for radiation shielding.

In simple terms, a linear accelerator works by employing microwaves to accelerate the electron beam. Faculty

working at Stanford on microwaves for radar during WWII had apparently visualized the possibility of accelerating electron beams.

In any text on microwaves, it is noted that the  $TM_0$  mode of a circular wave guide has an electric field along the guide. It is just this electric field which can be used to accelerate a charge. However, it is also noted that the phase velocity of any waveguide mode is greater than  $c$ , the velocity of light. But, Einstein's relativity theory tells us that an electron must have a velocity less than  $c$ .

To resolve this problem, the uniform waveguide (as used in a radar set, for example) has loading discs installed. These discs slow down the microwaves but require very high frequency stability from the microwave source. The accelerating process may be compared to a surfboard (electron) riding in phase with an ocean wave (the microwave) and staying at a point where it always gets a forward force.

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## RESEARCH CENTER

### RAD-HARD SEMICONDUCTOR CHIPS, *continued from page 16*

Professor **Alan Ross**, the Navy TENCAP Chair Professor, has studied soft errors in microprocessors and space systems. Associate Professors **John Ciezki** and **Robert Ashton**, Department of Electrical and Computer Engineering, have examined radiation effects in power devices and circuits, and Assistant Professor **Todd Weatherford** has examined solid state transistor modeling and material manufacturing issues.

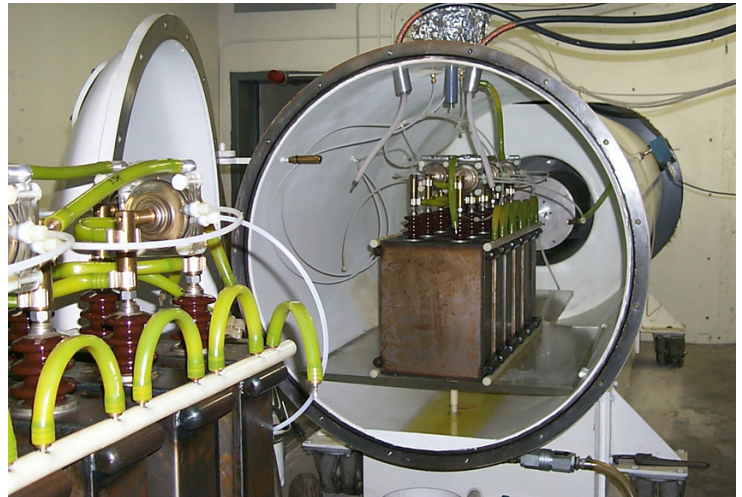
The radiation facilities at NPS are unique. The LINAC provides an electron beam pulse train of 100 MeV electrons (up to 1000 rads per microsecond pulse) useful for studying displacement damage in microelectronics or solar cells for applications in the Van Allen belts and even Jupiter's radiation belts. This is the only LINAC in operation that produces electrons in the 100 MeV energy range. The facility can also be used to study both Total Dose and some weapons effects. The Flash X-ray facility produces a gamma pulse of 100 rads in approximately 10-20 nanoseconds to simulate a weapons effect.

Both facilities are available to NPS faculty and outside users for periods of one month at a time, with up to 80 hours of "beam time" in a month. Charges are \$2500/month for faculty and \$9000/month for outside users.

As mentioned earlier, the availability of thesis students with clearance provides an advantage with many of the projects that are classified or limited to U.S. citizens. Addi-

tionally the NPS students are familiar with the satellite or weapon programs in which the research supports. Most student research has been involved in collaborations with industry such as; Motorola, Honeywell, Lockheed-Martin, Hughes, TRW, Vitesse Semiconductor, universities; UC

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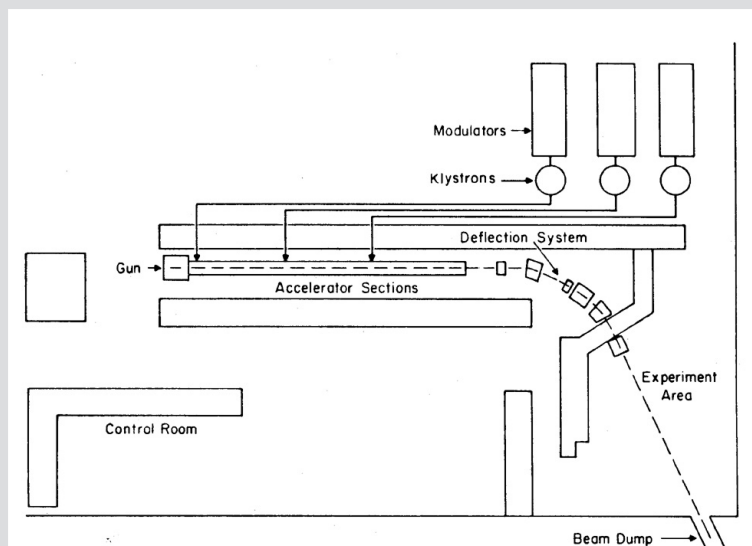


**The Flash X-ray facility shown opened for maintenance. X-rays are produced in an adjacent room after 1,200,000 volts are discharged from the capacitor banks shown inside the oil chamber.**

### THE "LINAC," *continued from page 16*

The realization of the NPS LINAC is shown in Figure 1, where each of three high power klystrons deliver power to one ten foot accelerator section. The klystrons require a high voltage high current source, called a modulator in the diagram. The electron beam is deflected by magnets to the experiment area. The energy of the electron beam is expressed in electron volts, one eV is the energy of an electron accelerated by one volt. Each 10-foot section gives energy of 30 million electron volts, i.e. 30 MeV per section. An advantage of the LINAC concept is that higher energy is obtained by having more accelerator sections. The NPS LINAC yields about 100 MeV from 3 sections, the Stanford Mark 3 accelerator yielded 1000 MeV from 30 sections, while the 960 section, 2 mile long Stanford Linear Accelerator Center (SLAC) accelerator yielded 20,000 MeV before the several upgrades.

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**Figure 1. Design of NPS Linear Accelerator.**

## PROJECT NOTES

### SABBATICAL BRINGS NPS PROFESSORS CLOSER TO THEIR GRADUATES

Professor **Carlyle (Chuck) Wash**, Chair of the Department of Meteorology, and his wife **Leslie Rosenfeld**, Research Associate Professor in the Department of Oceanography, recently completed a one-year sabbatical during which they visited all the U.S. Navy Meteorology/Oceanography (METOC) centers and facilities around the world. Their travels have taken them to San Diego; Yokosuka, Japan; Pearl Harbor; Mississippi, Jacksonville, FL; Norfolk, VA; Washington D.C.; London; Bahrain; Naples, Italy; Rota, Spain; and Whidbey Island, WA for visits ranging in length from one to six weeks. In addition to sabbatical funding from NPS, Professor Wash is funded by the Commander, Naval Meteorology and Oceanography Command (CNMOC) and the Office of Naval Research (ONR); while Professor Rosenfeld is funded by ONR. His focus was on helping the METOC centers learn how to make effective use of their new numerical modeling capability to produce better mesoscale atmospheric forecasts for operations in their areas of responsibility (AORs). Her emphasis was on evaluating and providing feedback on how the centers utilize ocean models and data to help the fleet. They were also both instrumental in putting the new Science and Technology Officers (STOs) at the centers in touch with resources that could aid them in addressing operational needs identified by their commands.

The payback for NPS is in what Professors Wash and Rosenfeld have learned about the jobs of their departments' graduates after they leave NPS. Besides positions at the METOC centers, facilities, and detachments, METOC officers (designator 1800) may be assigned to aircraft carriers, large-deck amphibians, and fleet, carrier-group, and submarine staffs, among other places. They are tasked with a wide range of duties including, but not limited to, those associated with their expertise in meteorology, oceanography, and marine charting and hydrography. At the centers and facilities, the METOC community (including 1800 officers, AGs, STGs, and other enlisted ratings,

and civilians) produce meteorological and oceanographic forecasts and products to support the surface fleet, submarines, aircraft, and special operations. In their extended visits, Professors Wash and Rosenfeld were able to observe, and participate in, these activities which were carried out in support of routine operations, fleet exercises, and actual missions. They hope to turn some of these scenarios (mass whale stranding, Kursk sinking, airplane crashes) into class laboratory exercises. They brought back a wealth of ideas on how to make their curricula more relevant to the Navy METOC mission.

Professors Wash and Rosenfeld's activities at the METOC centers included conducting training (individual, small group, or formal presentations), evaluating analysis and forecast products, and recommending ways to improve command knowledge and operations. Training topics included: uses of mesoscale numerical forecast models, advances in marine satellite remote sensing, use of ocean circulation models, forecasting with ensembles, and other subjects. During the sabbatical, they also prepared reports on selected topics,

*--continued on page 21*



**Professors Wash and Rosenfeld aboard the *USS Enterprise*, CVN-65, 100 miles off the mid-Atlantic Coast.**

# PROJECT NOTES

## SYSTEMATIC APPROACH TO TROPICAL CYCLONE TRACK FORECASTING

Research Associate Professor Lester E. Carr, III  
Distinguished Professor Russell L. Elsberry  
Department of Meteorology

### Introduction

Tropical cyclones are a major threat to Fleet units afloat and bases ashore. The Joint Typhoon Warning Center in Pearl Harbor, Hawaii, is responsible for providing DoD units warnings of tropical cyclones in the western North Pacific and in the Southern Hemisphere to the east coast of Africa. This center, which moved from Guam in January 1999 due to a base closure action, has re-started in Pearl Harbor with a nearly 100% turnover in personnel.

The meteorology groups in Monterey provide essential support for the Joint Typhoon Warning Center. The Fleet Numerical Meteorology and Oceanography Center provides numerical analyses and forecasts as well as some satellite data. The Naval Research Lab – Monterey has developed a number of those forecast products, and also the Automated Tropical Cyclone Forecast System that assists the forecaster in data handling, visualization, and warning preparation. The Department of Meteorology faculty research and theses have contributed many of the scientific bases for new products.

A long-term research project entitled the “Systematic Approach to Tropical Cyclone Track Forecasting,” led by the authors has come to fruition this summer with an operational test at the Joint Typhoon Warning Center. Basic research in the understanding of tropical cyclone motion sponsored by the Office of Naval Research (ONR) began more than a decade ago. A new ONR applied research project to incorporate these new understandings in a knowledge-based expert system was begun in 1996. More recently, the Space and Naval Warfare Command has provided funding to transition the research to operations at the Joint Typhoon Warning Center.

### Research Goals

The long-range objective is to provide a product that will assist the forecaster in reducing tropical cyclone track forecast errors at 72 hours to the Joint Chiefs of Staff goal of 150 nautical miles. The primary guidance used by the forecaster to make these forecasts in the western North Pacific come from international numerical weather forecast centers: a global and a regional model from Fleet Numerical Meteorology and Oceanography Center; global and regional model from the Japan Meteorological Agency; and a global model

from the United Kingdom Meteorological Office. Since 1994, these dynamical models have been markedly improved for tropical cyclone track forecasting. However, the model track forecasts still occasionally have large errors, sometimes as large as 1000 nautical miles after 72 hours. What is needed is guidance on when to accept or to reject the model track guidance for a particular tropical cyclone.

Thus, the short-term goal was to develop an expert system module that would assist the forecaster in rejecting dynamical model track guidance that is likely to be in error by more than 300 nautical miles at 72 hours. The result of rejecting that erroneous model track should lead to a more accurate warning than if all five model tracks were simply averaged.

### Dynamical Model Traits Knowledge Base

An exhaustive study was made of all large track errors made by the two Navy models during the 1997 tropical cyclone season. Approximately one third of all 72-hour forecasts have these large errors. Seven frequently occurring track-error mechanisms were discovered. Conceptual models were developed that describe how the error mechanisms appear in the wind and/or sea-level pressure forecast fields. Comprehensive case studies that illustrate the evolution of these wind or pressure fields over 72 hours were developed for the guidance of forecasters. This information was collected in a NPS technical report issued in June 1999. Subsequent studies, including a M.S. thesis by LT Dave Brown, USN, have demonstrated that these same error mechanisms apply for large track errors by other dynamical models and in other tropical cyclone basins.

### Expert System Module

Whereas the above dynamical model traits knowledge base was retrospective, a tool was needed to assist the forecaster in recognizing in real-time that a track forecast was likely to be erroneous. Programming the expert system module turned out to be a formidable task because the information has to be provided in a logical manner, be rapidly available, and be “forecaster-friendly.” Jim Peak of the Computer Sciences Corporation, who previously worked for the Naval Postgraduate School, did most of the expert system coding. The Automated Tropical Cyclone Forecast System developed by the NRL-Monterey was helpful in providing the necessary data streams.

*--continued on page 21*

# PROJECT NOTES

## NPS TEAMS WITH TRAC ON ACQUISITION CENTRALL

The TRADOC Analysis Center–Monterey (TRAC-MTRY) recently teamed with Assistant Professor **Keith Snider** of the Systems Management Department in the design, development, and operation of a virtual research and lessons learned capability known as the Acquisition Center for Research and Lessons Learned (Acquisition CENTRALL). The Acquisition CENTRALL virtual center is an internet-based system. Utilizing the capabilities and modern technology associated with the Internet, Acquisition CENTRALL will be a central repository of information to facilitate learning among members of the acquisition community. It links the knowledge resources of the acquisition professionals with the research resources of those who study acquisition.

Through Acquisition CENTRALL, acquisition practitioners submit lessons learned, good ideas and challenging issues that need further study for resolution. These submissions reside in the Acquisition CENTRALL database, which will enable several benefits to be achieved. First, as the number of submissions grows, this database will represent a catalog of “high-payoff” targets that will focus acquisition research efforts. Second, the database will facilitate knowledge sharing by providing a way for acquisition professionals to disseminate their lessons, ideas and issues to other practitioners. Third, users who are reviewing a lesson, idea or issue in the database can provide comments or responses, which allows for productive dialogue and discussion within the acquisition community. Acquisition CENTRALL also serves as an on-line repository for products such as research papers, student theses and other study project results. Readers of these products may provide comments or responses that become addenda to the products.

Organization of the Acquisition Web Portal is a three-tiered model. The first tier is the user interface. A user may log on to the site, access database files through an intranet, review lessons learned and research, submit comments to lessons learned and research or submit their own lessons learned or research files. The second tier is the web server that allows numerous users to access the same data, at the same time, from anywhere in the world. Finally, the third tier is a Microsoft Access 97 database for storing site end user information.

Until now, the acquisition community lacked tools, processes and procedures for capturing and disseminating “lessons learned.” Because so few “lessons learned” have been recorded or stored in a central location, it is difficult to assess the extent to which lessons should have been applied in various situations. Additionally, in the current defense

acquisition community, practitioners have few opportunities, resources and incentive to reflect upon, assess and report their experiences.

Benefactors include both policy makers and warfighters. It is envisioned that, as the database of submissions grows, policy-makers will gain greater insights into the nature of significant acquisition issues. Of course, policy-makers will also have opportunities to make submissions to Acquisition CENTRALL. Further, warfighters will have the same opportunity. Acquisition CENTRALL represents a potential key resource for enhancing

dialogue and a common understanding of issues between the acquisition and operational communities.

The secondary focus of this work is the displaying of theses by acquisition students, specifically from the Naval Postgraduate School. Several theses from NPS students have already been identified by Dr. Snider as excellent submissions to the database, and more are currently being reviewed. Posting theses research to the web-site gives visibility to the research already conducted by previous students. For current acquisition students, the web portal serves as a source for possible thesis topics identified by the acquisition community. Additionally, it can provide resources for several courses (e.g., MN3221, MN3222, MN3331, MN4307). To the extent that NPS researchers can address critical issues and challenges identified by policy-makers and practitioners, Acquisition CENTRALL will enhance NPS's position as a research institution and, particularly, as a leading institution for acquisition research.

Do you have a research paper or lesson learned that you would like to submit? Are you looking for information in the acquisition field? Check out Acquisition CENTRALL at [www.acquisitioncentrall.army.mil](http://www.acquisitioncentrall.army.mil).

## PROJECT NOTES

### SABBATICAL BRINGS PROFESSORS TO GRADUATES, *continued from page 18*

including recommendations on training, and summaries of Navy ocean circulation and tide models, and surface wave models.

In addition to interacting with the staff of the centers and facilities, they took every opportunity to visit with other METOC officers assigned to ships and staffs in the area. These ranged from training sessions with detachments primarily supporting airfields, to brainstorming with submarine group oceanographers. They also visited with other local government and research meteorological and oceanographic facilities, such as Scripps Institute of Oceanography, University of Tokyo, Old Dominion University, University of Cadiz, National Weather Service, and National Ocean Service, and facilitated Navy contacts with these institutions. At dockside, they were able to tour the spaces and examine the equipment used by OA divisions and Mobile Environmental Teams on a number of ships. They flew out to the carriers *USS Enterprise* off Norfolk, and *USS Eisenhower* in the Arabian Gulf, for overnight stays.

Professor Wash has been a faculty member at NPS since 1980, and it was particularly gratifying for him to see so many of his former students enjoying successful careers. Wherever he went, he solicited candid feedback from METOC alumni on their experiences here at NPS. These firsthand evaluations were overwhelmingly favorable, but also provided valuable insight into improvements that could be made. Wash and Rosenfeld also met some of our foreign alumni in Japan and Spain who spoke very highly of their time at NPS and were grateful for the education they received and the kindnesses they were shown. Professors Wash and Rosenfeld were the lucky recipients of their hospitality in

return.

Prior to embarking on the sabbatical, Professors Wash and Rosenfeld anticipated that much of their interaction would be with the officers and civilians. One of the unexpected pleasures on the trip was to work with so many bright and engaging enlisted personnel. For the most part, they were eager to learn new things and many sought out the professors to ask questions. In addition, the professors met many junior officers at these centers who were in their first or second METOC tour. These officers had many questions about NPS and were anxious to learn about the METOC curricula. Wash and Rosenfeld look forward to greeting these officers when they arrive at NPS for their graduate education tour.

Prior to leaving each center or facility, Wash and Rosenfeld briefed the Commanding Officer (CO) on what they had learned – both good points and bad – about the command's operations. They presented detailed suggestions and are following this up with a written report to each CO. They plan to compile their findings and recommendations into a comprehensive report to be presented to CNMOC and ONR. Wash and Rosenfeld plan to share their observations with their METOC NPS colleagues through a seminar on their experiences. These forward-deployed professors returned to NPS this fall with great respect for the METOC officers, sailors and staff, and a much better understanding of how they serve the fleet and the problems that they face and must solve. In addition, they hope their findings will improve the NPS METOC curricula in meeting the challenge of educating the METOC officers of the future.

### TROPICAL CYCLONE TRACK FORECASTING, *continued from page 19*

A beta test of the expert system module was carried out at the NPS late in 1999. Research Associate Professor **Patrick Harr**, Research Assistant Professor **Elizabeth Ritchie** and Meteorologist **Mark Boothe** participated in the simulated real-time test of the expert system module. This beta test was a valuable learning experience and led to a number of improvements in the module. The test was successful in the sense of correctly rejecting nearly all erroneous 72-hour track forecasts. Even though the Joint Typhoon Warning Center had their best year ever, we were able to show that the expert system had the potential to help them be even better.

#### Delivery of the Expert System

Again with some special funding from SPAWAR, a preliminary version of the expert system was delivered in May 2000 for training and familiarization by the forecasters. A final version was delivered in early July, and the forecasters have been utilizing the expert system as a primary tool in their forecast process. Half-way through the 2000 western North Pacific tropical cyclone system, the Joint Typhoon Warning Center is having another record-breaking year for accuracy. They credit the Systematic Approach Expert System developed at NPS for contributing to that success.

# STUDENT RESEARCH

## OPTIMIZATION OF UNITED STATES MARINE CORPS OFFICER CAREER PATH SELECTION

Major Peter B. Baumgarten, United States Marine Corps  
Master of Science in Operations Research-September 2000  
Advisors: Associate Professor Siriphong Lawphongpanich  
and Research Assistant Professor Alexandra Newman,  
Department of Operations Research

The Marine Corps Manpower System is responsible for managing the Marine officer inventory. The system's primary objective is to maximize the Marine Corps' operational readiness through the assignment of officers to billets. While striving to fulfill billet requirements, the manpower system simultaneously develops the professional skills, or core competencies, that each officer must possess to be assigned to billets requiring more authority and responsibility. Therefore, officer careers (or career paths) must reflect a balance between fulfilling billet requirements and developing core competencies. Currently, Marine Corps manpower

planners lack rigorous methods to assist them in understanding the effects of various personnel policy decisions on the average officer career path or the system's ability to meet future billet requirements.

To assist these planners, this thesis presents an integer program, the Officer Career Path Selection (OCPS) model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. This thesis uses data from the Infantry Marine Occupational Specialty (MOS) to illustrate that outputs from OCPS provide useful information regarding the number of annual Infantry officer accessions and the effects of potential manpower policy decisions. (Major Baumgarten is the recipient of the Military Operations Research Society Stephen A. Tisdale Graduate Research Award.)

## EXPLORATION OF FIBRE CHANNEL AS AN AVIONICS INTERCONNECT FOR 21ST CENTURY MILITARY AIRCRAFT

LCDR Shawn Hendricks, United States Navy  
Master of Science in Aeronautical Engineering and  
Aeronautical Engineer-June 2000  
Advisors: Associate Professor Russ Duren, Department of  
Aeronautics and Astronautics, and Assistant Professor John  
McEachen, Department of Electrical and Computer  
Engineering

Avionics architectures are evolving from "Federated" systems consisting of highly specialized black boxes connected together via MIL-STD-1553 and ARINC 429 data buses to "Integrated" and "Distributed" architectures. These new architectures contain high data-rate sensors, parallel processors, and shared memory with high levels of integration. These systems require a new interconnection system that overcomes the limitations of older standards. One such interconnection system is Fibre Channel. This thesis evaluates Fibre Channel as an avionics interconnection standard. It begins by defining the requirements and measures of performance for an interconnection system suitable for the new avionics architectures. The requirements address technical performance, affordability, reliability, sustainability, and maintainability considerations. The Fibre Channel standards are then compared to

the requirements for the avionics interconnection system. In order to perform a technical performance evaluation of a switched fabric avionics interconnection system, a computer simulation model was developed. The OPNET Modeler® tool from OPNET, Inc. was used to model the components of an advanced avionics system. This tool allows multiple system configurations to be defined and examined quickly; showing both the advantages of one configuration over another as well as potential problem areas. (LCDR Hendricks' work was performed at the request of the Joint Strike Fighter Program Office. The Fibre Channel standard is being considered for use in the JSF avionics system.)

**Oceanography doctoral candidate LT Fabrice Arduin, French Navy, received the Outstanding Student Paper Award from the American Geophysical Union for his paper, "A Hybrid Eulerian-Lagrangian Numerical Model for Wave Evolution in Shallow Water." The paper was presented at the Fall Annual Meeting of the AGU. The paper has since been accepted for publication in the *Journal of Physical Oceanography*. LT Arduin is advised by Associate Professor Tom Herbers, Research Associate Professor Tim Stanton, and Oceanographer William O'Reilly of the Department of Oceanography.**

## INTELLIGENT AGENTS FOR NAVY ACQUISITION INNOVATION

LCDR David N. Fowler, United State Navy  
Master of Science in Management-December 1999  
Advisor: Assistant Professor Mark E. Nissen, Department  
of Systems Management

Information technology has advanced to the point at which software agents can be developed to represent people in their conduct of business processes. Enabled by a modicum of artificial intelligence, such software artifacts are termed *intelligent agents*, and recent thesis work by Naval Postgraduate School (NPS) faculty and thesis students is applying this advanced technology to the acquisition domain. The students are building on research conducted by Assistant Professor Mark Nissen, who has long been investigating process innovation through knowledge technologies such as intelligent agents. Their work is inspired, in part, by a proof-of-concept agent application called The Intelligent Mall, which demonstrates the use of intelligent agents to automate key aspects of the enterprise supply chain.

In his thesis effort, entitled *Innovating the Standard Procurement System Utilizing Intelligent Agent Technologies*, LCDR David Fowler, USN, examines opportunities for agents to innovate the Navy acquisition process. Acquisition activities—such as procurement, contracting and logistics—are becoming increasingly important, as the Navy and other services strive to shorten the cycle time required for weapon system development and be more responsive to warfighter needs in the field. At present, the acquisition process is time-consuming, expensive and labor-intensive, with a mixed record of satisfying warfighter needs.

The current DoD approach to this problem is to pursue development and implementation of what is referred to as the Standard Procurement System (SPS), which is a large software application used to enable workflow capabilities in support of the procurement and contracting processes. SPS provides some capability for paperless contracting and possesses the necessary infrastructure to begin a transition to electronic business. For instance, it replaces paper forms (e.g., purchase requests, requests for quotation, purchase orders) with electronic counterparts and automatically routes such work products to various people in the organization (e.g., requestors, managers, contract specialists). However, as a relatively novel information system implementation, SPS remains quite crude and has limited functionality. And this information system is being implemented worldwide without first redesigning the underlying procure-

ment and contracting processes.

The objective of this thesis is to identify avenues for emerging agent technologies to innovate the acquisition process, with the goal of enabling order-of-magnitude gains in performance (esp. cost and cycle time).

LCDR Fowler acquired considerable acquisition expertise as a student at NPS, where he was exposed to SPS. He leveraged this knowledge and exposure to investigate the potential role that intelligent agents could play in process redesign. He also acquired familiarity with the capabilities of the Intelligent Mall, in order to ground his analysis in agent capabilities that are becoming available today. Using the Davenport-Nissen framework for process analysis, he conducted a detailed examination of the Federal Acquisition Process and identified many serious pathologies, along with numerous process activities the SPS fails to support. He then employed a four-step method for evaluating agent potential, which he used to identify and rank-order several acquisition process activities with particularly-good potential for automation and support through intelligent agent technology. Each of these was in turn evaluated in the context of two process redesign alternatives, both of which offer excellent opportunity for the kinds of quantum performance gains desired through innovation.

Several key results emerge from this thesis research. First, the current DoD approach (i.e., SPS) is seriously flawed. Although SPS represents a step in the right direction (e.g., moving toward paperless contracting), the underlying acquisition process it supports remains inefficient, and laying SPS on top of this existing process is expected to make cost and cycle time *increase*. Second, agent technology that is available today offers excellent potential to enable quantum performance improvements in Navy acquisition processes. And such agent technology can be developed to integrate with SPS and other existing Navy systems, thereby leveraging the investment already made in such systems. Third, restructuring the underlying acquisition process—in addition to developing systems for support—offers great potential for performance improvement and lies within the authority of Navy leaders to undertake. Fourth, because agent technology continues to develop and mature, not all acquisition process activities should necessarily be addressed by agents at the present time. Rather, the thesis identifies those near-term process activities (e.g., market research) that offer the best potential for agent-based support today, along

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# STUDENT RESEARCH

## TRUST AND ITS RAMIFICATIONS FOR THE DOD PUBLIC KEY INFRASTRUCTURE (PKI)

LCDR Leonard T. Gaines, United States Navy  
Master of Science in Information Technology Management  
and Master of Science in Computer Science—September 2000  
Advisors: Assistant Professor James Bret Michael, Department  
of Computer Science, and Lecturer Rex Buddenberg, Informa-  
tion Systems Academic Group

In order to incorporate trust into e-commerce, public key cryptography, and basic communication, one must understand and effectively manage trust. Various Internet security protocols have attempted to address this lack of trust. However, these protocols do not incorporate the user's trust into these protocols. Computational models of trust have been developed in an attempt to automate the logic, variables, and thought processes that a human performs when making a trust-decision. Due to the fact that trust is based on a subjective

belief, the models require the assignment of metrics to belief variables or attributes that will have value when evaluating trust. These models address the notion of trust in many different ways and both their definitions and metrics vary significantly. This thesis evaluates the various trust models. It is necessary to understand how trust is defined in each model in order to evaluate how well the operation of a system based on the model satisfies the requirements of the users. Trust models are evaluated based on their characteristics, environmental references, metrics, variables used, and outputs. This thesis concludes with the assessment of a practical application of a trust model to the DoD's PKI system. (LCDR Gaines is the recipient of the Monterey Council Navy League Award for Highest Academic Achievement.)

## THE FEASIBILITY OF USING DESIGN RATIONALE TO AUGMENT THE IMPLEMENTATION STRATEGY OF MANAGED CARE

CDR Daniel J. Zinder, United States Navy  
Master of Science in Information Technology  
Management—September 2000  
Advisors: Associate Professor Kishore Sengupta and  
Professor Daniel Dolk, Information Systems Academic  
Group

The feasibility of using argumentation based design rationale capture techniques for improving the implementation strategy of managed care is investigated. The hypothesis is made that managed care is failing because it deals in "wicked" problems, which are fundamentally different than the "tame" problems encountered in traditional medicine, and that the organizational structure of managed care is not equipped to handle wicked problems. It is shown that argumentation based design rationale tools are an excellent candidate for bridging the ideals of traditional medicine to the realities of managed care for three reasons: the tools are specifically designed to explore the resolution of wicked problems, the problems encountered in managed care possess many similarities to problems that have been shown to have successful utilization of design

rationale capture techniques, and the power relationships within managed care are most fitting with a collaborative implementation strategy. Recommendations for a collaborative implementation strategy of managed care, using design rationale capture tools as a mechanism of collaboration, are given. (CDR Zinder is the recipient of the Rear Admiral Grace Murray Hopper Information Technology Management Award.)

## INTELLIGENT AGENTS FOR NAVY ACQUISITION,

*continued from page 23*

with a migration plan for addressing other process activities as agent technology continues to mature. Fifth, the results of this thesis are not limited to Navy acquisition processes (e.g., equally applicable to the Marine Corps, Air Force, Army), and agent technology also offers good potential to support warfighter needs directly (e.g., in terms of intelligence, surveillance). Finally, the conclusions of this thesis have been validated in several respects, and the key ideas are presently under consideration for development of future SPS capabilities by the DoD and its commercial vendor. The thesis also provides a sizeable step in terms of new knowledge, and it lays a solid foundation, on which others can build. Indeed, the Navy now has a new agent-savvy officer in its ranks.

# STUDENT RESEARCH

## MOVES GRADUATES ITS LARGEST CLASS

The Naval Postgraduate School's Modeling, Virtual Environments and Simulation (MOVES) Academic Group held its first open house on the 30<sup>th</sup> and 31<sup>st</sup> of August to celebrate four years of operation and the graduation of its largest class ever, 13 Masters degrees in MOVES. Each graduating student gave a presentation on their thesis, as well as an evening demonstration of their developed software in the MOVES Research Center.

Presentations ran the entire gamut of the MOVES research spectrum. There was presented work on human-computer interaction, networked virtual environments, computer-generated autonomy, defense and entertainment collaboration, and modeling and simulation. The first presentation of the George L. Phillips Modeling, Virtual Environments and Simulation Award to a graduating student, LCDR Kim Roddy, USN, was also celebrated.

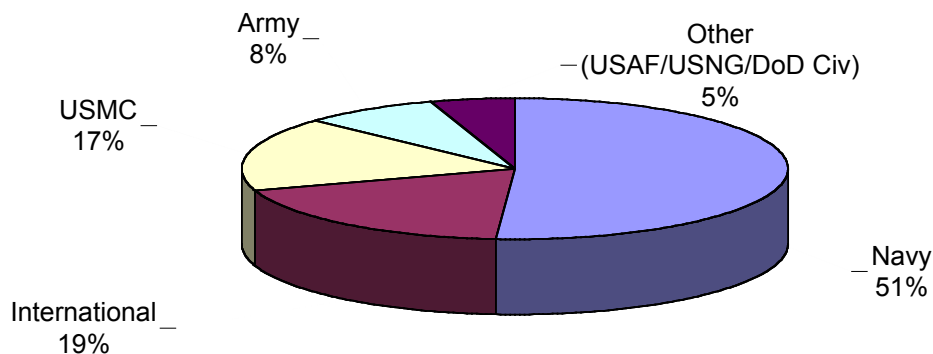
In addition to the student presentations, there were several talks by faculty on the big picture with respect to the student work. Highlights included Assistant Professor Rudy Darken's

overview of human-computer interaction in MOVES, Assistant Professor Don Brutzman's overview on web-based virtual environments research, Research Professor John Hiles' multi-agent systems overview, Professor Michael Zyda's entertainment research directions overview, and Associate Professor Tom Lucas' joint combat modeling course overview.

Forty external visitors attended the open house, including the Deputy Assistant Secretary of the Army for Manpower and Reserve Affairs, John McLaurin. Deputy McLaurin combined the MOVES Open House with a review of the Army Game Project spearheaded by the MOVES Academic Group and the NPSNET Research Group. The staff of N6M, the Navy Modeling and Simulation Management Office, the Director of Research and Development of the Defense Modeling and Simulation Office, were also in attendance. Presentation slides and the agenda from the open house are available on the web at <http://www.npsnet.org/~moves/OpenHouse/OpenHouseAgenda.html>.

**THE THESIS:** The thesis is the capstone achievement of the student's academic endeavor at NPS. Thesis topics address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain long-term superiority of the Navy/DoD.

Students, with their faculty advisors, provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are rapidly being developed in both the commercial and military sectors. Their unique knowledge of operations, when combined with a challenging thesis project which requires them to apply their focused graduate education, is one of the most effective methods for solving both Fleet/Joint Force problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.



**Student Demographics: September 2000**  
(1347 Students in Residence)

# RELATIONSHIPS

## TECHNICAL AND RESEARCH ASSISTANCE IN SUPPORT OF THE JOINT C4ISR BATTLE CENTER

The organizational relationship regarding the technical and research assistance provided by the Naval Postgraduate School (NPS) in support of the Joint Battle Center Mission was formalized by a Memorandum of Understanding between NPS and the Joint C4ISR Battle Center.

The Joint C4ISR Battle Center (JBC) is responsible for conducting assessments of issues related to fielding Joint C4ISR systems, including methods for achieving interoperability within a C4ISR “system of systems” composed of both legacy and developmental C4ISR systems. JBC provides reports to the Joint Requirements Oversight Council (JROC) with recommendations regarding such issues. NPS has expertise on many system-related issues and access to students from all branches of DoD with expertise on military issues. The purpose of this agreement is to establish a procedure for identifying and funding projects to be carried out by NPS that contribute to the mission of JBC.

The JBC is staffed by Warfighters, C4ISR subject matter experts, and technologists. It is an organization which brings the Warfighter directly into the assessment process. The assessment methodology, combined with the organizational uniqueness of the JBC, lowers barriers between Warfighters and technologists by creating a powerful environment for joint operational innovation and interoperability demonstrations and assessments. To do this, the JBC provides a re-configurable JTF C4ISR laboratory/network and assessment environment. In addition, the JBC is located in close proximity to the Joint Training Analysis and Simulation Center (JTASC) which conducts the Unified Endeavor (UE) series of operational exercises. This proximity and relationship are absolutely

fundamental to the successful execution of the JBC mission and charter. It is this environment that allows Warfighters and technologists to see, touch, and feel the C4ISR capabilities to be used in combat. This environment allows rapid assessment of JTF- required maturity, interoperability and utility. It allows the creation of technology insertion solutions to current JTF problems, and assessment of those solutions. It creates a venue for the dynamic interaction of emergent technology with operational doctrine-another fertile field for technologist/Warfighter collaboration. The objective of the JBC is to provide a fielded interoperable capability, meeting the Joint Warfighter’s needs as defined through the CINC’s requirements process and using technological advancements on an accelerated basis. The JBC identifies systems that clearly demonstrate joint “value added” for potential rapid fielding. Systems that do not demonstrate joint interoperability may be recommended for either improvement or elimination.

NPS has academic experts responsible for providing advanced education and conducting research in many related areas. NPS is one of the leading centers of excellence, which has won numerous research awards and has pioneered the establishment of Engineering Ph.D. programs in the U.S. NPS has many M.S. and Ph.D. students who are eager to conduct thesis research that contributes to the DoD and the mission of JBC.

The principal objective of this agreement is to establish a direct relationship between NPS and JBC for mutual cooperation and benefit. It will provide a mechanism by which M.S. and Ph.D. students and faculty can conduct research that contributes to the DoD and the mission of JBC.

## SUBMARINE TACTICAL DEVELOPMENT SUPPORT BY NPS

A Memorandum of Understanding formalized the relationship between the Naval Postgraduate School (NPS) and Submarine Development Squadron Twelve (SUBDEVRON TWELVE). The goal of this relationship is to take advantage of the Navy’s unique academic institution at NPS, leveraging their expertise in Operations Research and Undersea Warfare (USW) disciplines to increase the Submarine Force’s combat effectiveness. Through the NPS faculty, students will be encouraged to pursue thesis work on projects that will benefit Submarine Force tactical development. Additionally, NPS’ expertise in technological change and innovation, statistical modeling, algorithm development, and their evaluation of emerging technologies will be sought out for USW applications. Finally, NPS graduate students will be exposed to SUBDEVRON TWELVE’s mission, with the prospect for a follow on staff tour.

# RELATIONSHIPS

## ENGINEERING ACOUSTICS CHAIR ESTABLISHED AT NPS

A Memorandum of Understanding (MOU) was formalized between the Naval Postgraduate School (NPS) and the Space and Naval Warfare Systems Center (SSC)-San Diego for the establishment and support of the Engineering Acoustics Chair in the Department of Physics at NPS.

Sonar systems development and its applications to Navy missions are of primary concern to SSC-San Diego. The Engineering Acoustics (EA) Academic Committee at NPS was formed to foster research and graduate education for Naval officers and employees in this field of study. The Engineering Acoustics Chair will bring additional expertise to NPS in this crucial area, provide research and curricular leadership, and enhance coordination of activities in this area between SSC-San Diego and NPS programs. The general purpose of the Chair is to advance sonar system science, technology, require-

ments, and concepts, and to assist SSC-San Diego in defining sonar system development directions. The MOU identifies the broad roles and responsibilities of the parties entering into the agreement.

Mr. **Joseph Rice** of SSC-San Diego will join NPS in January 2000 as the first Engineering Acoustics Chair Professor. Under the technical leadership of Mr. Rice, SSC San Diego is pioneering the use of acoustic energy and digital communications for undersea wireless telemetry, a technology now known as telesonar. In addition to fulfilling the terms of the agreement, Mr. Rice will continue to pursue his research in the emerging field of telesonar, with particular emphasis on signaling, channel adaptation, directional transducers, distributed networks, and Naval applications.

## NPS CHAIR PROFESSORSHIPS ARE A VALUED ASSET

NPS currently has over twenty Chair Professorships. A Chair is established by a Memorandum of Understanding/Agreement with a sponsoring activity. The agreement outlines the scope of the position and lists the responsibilities of the partners to the agreement. Chair Professors work closely with both students and faculty, as well as serving as a link to the external partner.

- Conrad Chair of Financial Management
- Chair of Strategic Planning
- Naval Space Systems Academic Chair
- Navy TENCAP Chair
- Naval Space Technology Program Chair
- National Security Agency Cryptologic Chair
- NASA Michael J. Smith Space System Chair
- Chair of Tactical Analysis
- Chair of Logistics
- Chair of Arctic Marine Science
- Chair of Mine Warfare
- Chair of Manpower Modeling
- Chair in Applied Systems Analysis
- Admiral Boorda Chair of Management and Analysis
- RADM George F. Wagner Chair in Public Management
- Lawrence Livermore National Laboratory Chair
- Measurement and Signature Intelligence (MASINT) Chair Professor
- Chair of Expeditionary Warfare
- Federal Aviation Agency Aviation Security Chair
- National Reconnaissance Office Chair Professorship
- Engineering Acoustics Chair

## CHAIR OF ARCTIC MARINE SCIENCE BEGINS 24<sup>th</sup> YEAR

The Office of Naval Research sponsored Chair of Arctic Marine Science will begin its twenty-fourth year at the Naval Postgraduate School. Professor **Ursula Schauer**, a senior scientist at the Alfred Wegener Institute for Polar and Marine Research at Bremerhaven, Germany, will be the next chairholder. Professor Schauer has had a distinguished career as an Arctic observational physical oceanographer with emphasis on water mass modification, shelf basin exchange and the interchange of the Nordic Seas with the Arctic Ocean.

During her tenure as the Arctic Chair, she will collaborate with Professor **Bert Semtner** and his colleagues, Research Assistant Professors **Wieslaw Maslowski** and **Yuxia Zhang** in their efforts to develop a very high resolution (9km horizontally) air-sea-ice model. Professor Schauer will also provide lectures and seminars to the faculty and students at NPS and assist with teaching in the Polar Oceanography class.

# CONFERENCES

## VIRTUAL EDUCATION AND THE FUTURE ROLE OF THE UNIVERSITY

Fifty leaders from academe, industry, accrediting bodies, government, and the military met August 8-9 in Monterey at a symposium co-sponsored by the White House Office of Science and Technology Policy (OSTP) and the Naval Postgraduate (NPS) to brainstorm on the impact on-line learning is having on universities and learning institutions everywhere. James Duderstadt, president emeritus of the University of Michigan and a keynote speaker at the symposium, described e-technology as "the most revolutionary technology since the printing press." Duderstadt said that universities must adapt not only to the exploding technologies but also to the complex economic, social, and cultural changes occurring throughout the world.

Congressman Sam Farr (D-Carmel) discussed recent Congressional hearings on the impact of information technologies on universities and invited attendees to advise him and other members of Congress on national policy to facilitate e-education, as well as specific legislative and regulatory issues associated with e-learning.

OSTP official Lori Perine reinforced the urgent need to understand how accelerating educational technology will transform the educational, economic, and social landscapes among institutions of higher learning. She also sought suggestions on how the federal government can address the growing digital divide and support undergraduate and graduate education for underserved populations.

**Carson Eoyang**, Associate Provost for Continuous Learn-

NPS' Information Systems and Operations On-line Program will begin in the Summer of 2001. Phase 1 will be offered beginning in October 2000 and consist of the following courses:

- Space Technology and Applications
- Principles of Information Operations/  
Information Warfare
- Probability and Statistics

*For additional info send e-mail to ISOADMIN@nps.navy.mil.*

ing at NPS and symposium organizer, viewed the meeting as a kickoff to a broader, richer, dialogue. "The growth of online learning is inexorable. The challenge for educational institutions is to prepare themselves to succeed in the world of virtual education."

"There's no question that the Information and Knowledge Revolution will be as central and defining to the 21<sup>st</sup> Century as the Industrial Revolution was to the 19<sup>th</sup> Century," said NPS Superintendent **RADM Richard Wells**. "The directions taken and decisions begun and made here will catalyze the process of shaping the role of education and learning in the New Economy."

The Conference was a watershed in the development of distributed learning. Participants in the symposium were insistent that a follow-up conference be held within the next several months.

## STRATEGY IN THE CONTEMPORARY WORLD

On 19-21 September 2000, the Department of National Security Affairs hosted a unique gathering of scholars from the United States and Great Britain. Working with a group of U.S. policymakers and officers, these researchers gathered to craft a comprehensive overview of contemporary security strategy. The project is a joint effort undertaken by Associate Professor **James Wirtz**, Department of National Security Affairs, Naval Postgraduate School, Eliot Cohen, Johns Hopkins School of Advanced International Studies, Colin Gray, University of Hull and John Baylis, University of Wales. The conference was part of a multi-year project supported by the Naval Information Warfare Activity and J9, Joint Forces Command. It is intended to apply traditional strategic concepts to both emerging and long-standing security concerns facing today's Joint Force

commander.

Highlights of the conference included University of North Carolina Professor Steven Biddle's presentation on land power, CAPT Sam Tangredi's (National Defense University) paper on sea power, and Sir Timothy Garden's (King's College-London) description of the evolution of airpower in the 20<sup>th</sup> century. Associate Professor **Daniel Moran** of the Department of National Security Affairs also provided a concise description of the evolution of strategic thought that will be used as an opening chapter for the study. Participants enjoyed a lively discussion as panelists and invited participants helped to focus the research project.

Oxford University Press will publish the results of the project in 2002.

# TECHNOLOGY TRANSFER

## NPS PARTNERSHIP WITH STIRLING DYNAMICS WINS NASA 2000 STTR PHASE I AWARD

The National Aeronautics and Space Administration (NASA) has selected 19 research proposals for negotiation of Phase I contract awards for NASA's 2000 Small Business Technology Transfer Program (STTR). The 2000 solicitation closed in May with NASA receiving 96 proposals submitted by small high technology businesses from across the United States. The combined award total for the 19 Phase I contracts is expected to be \$1,896,165. Companies which successfully complete the Phase I activities are eligible to compete for Phase II selection the following year. The Phase II award allows for a two-year fixed price contract in the amount up to \$500,000.

Stirling Dynamics, Inc., of Seattle Washington, proposal was selected with the Naval Postgraduate School as partner. Research Assistant Professor **Ramesh Kolar** of the Department of Aeronautics and Astronautics is the NPS point-of-contact.

The STTR goals are to stimulate technological innovation, increase the use of small businesses in meeting federal research and development needs, and increase private sector commercialization of results of federally funded research. The STTR Program requires small business concerns to conduct cooperative research and development by partnering with a research institution. At least 40 percent of the work must be performed by the small business concern and at least 30 percent of the work must be performed by the research institute.

## COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS ALLOW PARTNERSHIP WITH INDUSTRY

The Cooperative Research and Development Agreement (CRADA) is one of the principal mechanisms used by federal laboratories to engage in collaborative efforts with non-federal partners to achieve the goals of technology transfer. The CRADA mechanism, created by the Federal Technology Transfer Act of 1986, supports the broader purpose of providing the means for a federal laboratory to leverage its R&D efforts consistent with the lab's mission. Although not technically a lab, NPS' vigorous research program allows it to use this valuable mechanism.

Two CRADAs have recently been finalized, one with the General Electric Company, the other with Rockwell Science Center. NPS and the General Electric Company, acting through its GE Aircraft engines business component, GEAE, will do cooperative research in the development of pulse detonation (PD) technology. NPS will conduct analysis and testing of GEAE specified PD tasks. The program will advance the state of PD technology using liquid fuels. The NPS PD research program will benefit from the new technologies provided and from the expansion of current programs to include other liquid fuels. GEAE will benefit from the existing liquid-fuel capabilities at NPS, which, together with the proposed effort, will provide advancement in GEAE's capabilities for application to commercial and military applications.

NPS and Rockwell Science Center have entered into an agreement to develop high-pressured miniaturized thermoacoustic refrigeration. Thermoacoustic refrigeration represents an attractive phenomenon for thermal management purposes. Due to the absence of purely mechanical components, it has the potential for miniaturization to support chip-level cooling of electronic components. The collaboration will allow RSC a means to compare the results of alternative research and development efforts currently being pursued and will also provide quantitative technical information on potential future paths for performance enhancement. NPS personnel will be able to apply their established expertise in thermoacoustics to this miniaturized applications area.

### Current and past CRADA partners include:

- TRW
- Mission Research Corporation
- The Boeing Company
- SRI International
- Adroit Systems
- Analytical Graphics Inc.
- Advanced Network & Services Inc.
- Wang Federal Inc.
- DSO National Laboratory of the Republic of Singapore
- Delfin Systems
- Mississippi State University
- General Electric Government Services

## LAB NOTES

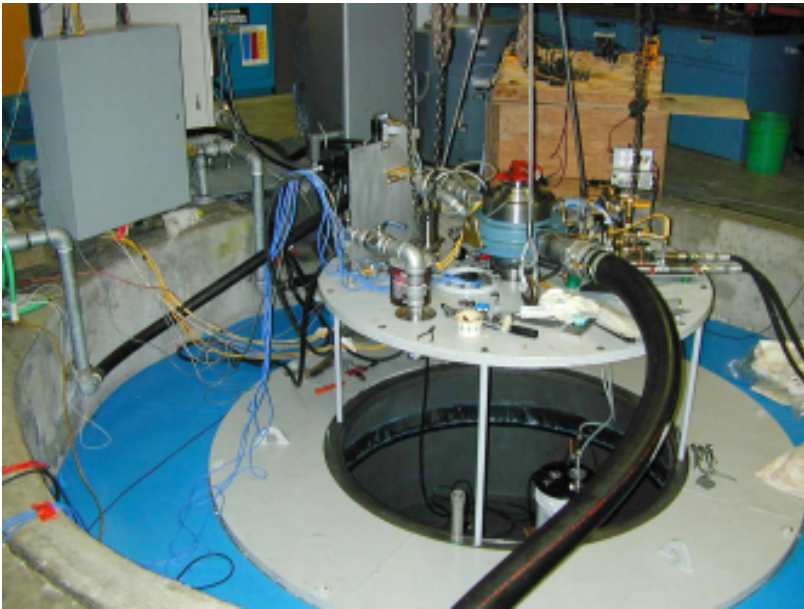
### REFURBISHED ROTOR SPIN FACILITY IN NPS' TURBO-PROPULSION LABORATORY REACHES SECOND MILESTONE

When 'High Cycle Fatigue (HCF)' became recognized as the most troubling issue associated with military aircraft engine reliability and durability, a National initiative began with the 1<sup>st</sup> and 2<sup>nd</sup> National Turbine Engine HCF Conferences held at the Naval Postgraduate School. During the 2<sup>nd</sup> Conference in 1997, the Navy proposed to contribute its 'Rotor Spin Facility' at Patuxent River, MD to conduct HCF-related structural tests, and to refurbish the engine-scale spin pit facility at the Turbopropulsion Laboratory (TPL) at NPS, to serve as the Navy's Rotor-Spin Research Facility. The goal of the NPS program was to develop, or evaluate, blade excitation and measurement techniques for HCF testing in vacuum spin pits, and to transition those techniques to the Rotor Spin Facility in Maryland.

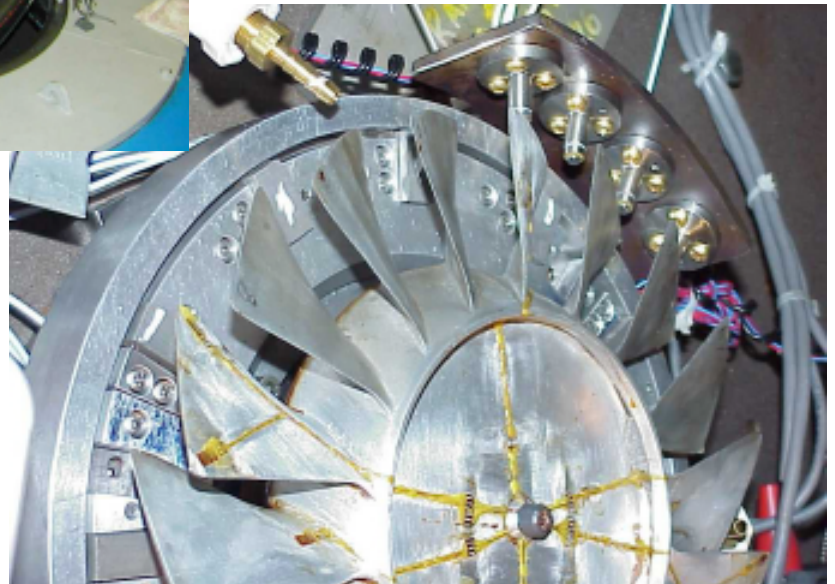
The first milestone was reached when the refurbished facility was reported (and toured) at the 4<sup>th</sup> National Conference again held at NPS in 1999. The second major milestone was reached this July, when blade resonance was excited in an eleven-inch aluminum fan rotor using both air-jet and eddy-current excitation (ECE) techniques. The measurement of the resonance was via strain gauges, using a very high speed slip ring assembly and real-time data acquisition. This success was reported at the Passive Damping Action Team Meeting held at Duke University.

The research team from the Department of Aeronautics and Astronautics involves Professor **Ray Shreeve** and Associate Professor **Garth Hobson**, with **Doug Seivwright** as the research project engineer. **John Gibson** (Rolands and Associates) is the assigned technician, and **Rick Still** is the support manager. Hood Technology Corporation are contracted by the Air Force to develop ECE, and an excellent working relationship has been developed between NPS and Hood.

In the future, the program will involve further experiments using the aluminum rotor, and then a small titanium rotor. This will be followed by ECE excitation of a nickel turbine rotor with experimental vibration dampers. This will be followed by the excitation of a 37-inch diameter fan from the Pratt & Whitney F119 engine (F22), and then a durability evaluation of a damaged JSF fan rotor.



Above: Rotor-Spin Research Facility in the Turbo-Propulsion Laboratory.



Right: Aluminum Test Rotor.

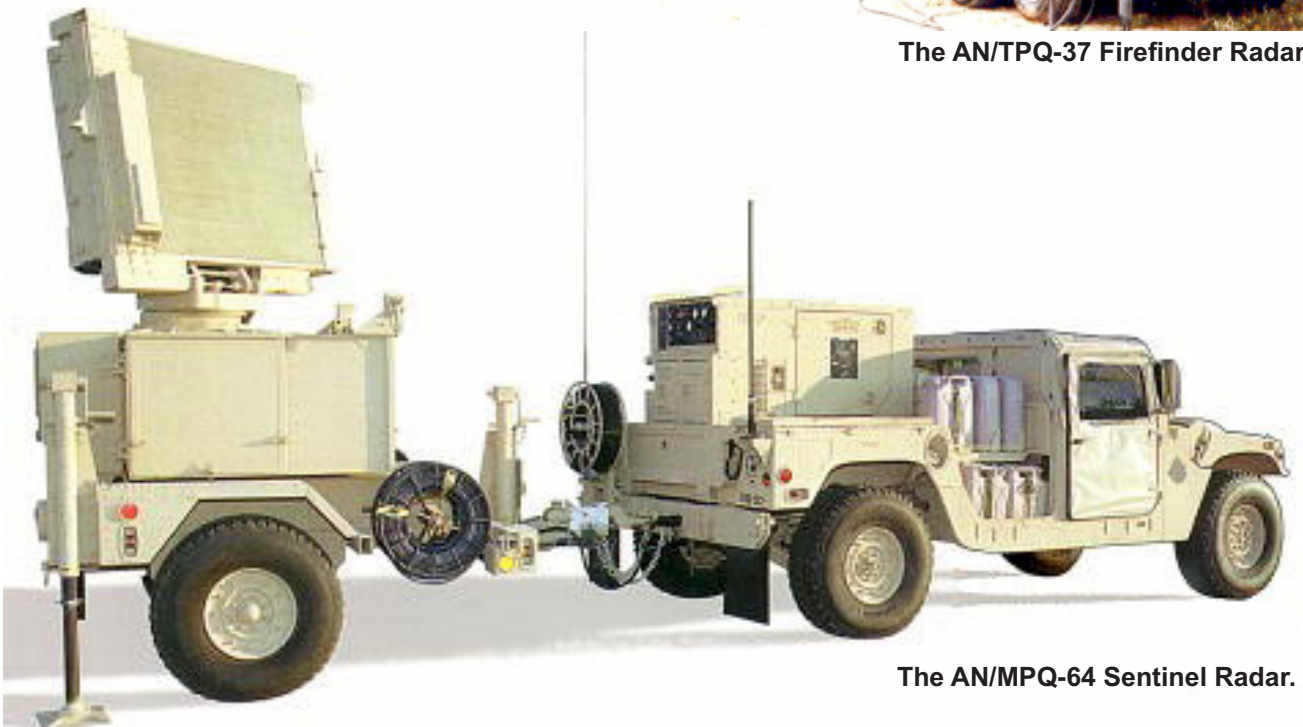
## LAB NOTES

### NEW ACQUISITIONS FOR THE RADAR AND ELECTRONIC WARFARE LABORATORY SUPPORT FACULTY AND STUDENT RESEARCH

The joint efforts of Professor **Jeffrey Knorr**, Chair, Department of Electrical and Computer Engineering (<http://web.nps.navy.mil/~ece/>) Research Associate **Bob Bluth**, Director of the Center for Interdisciplinary Remotely Piloted Aircraft Studies (<http://web.nps.navy.mil/~cirpas/>) and **Paul Buczynski**, Staff Director, Radar and Electronic Warfare Laboratory, have led to the acquisition of two new pieces of equipment to support faculty and student research. The AN/MPQ-64 Sentinel radar is a modern mobile, phased array, pulse doppler radar that will be modified so it can be used as an instrument for severe storm research. Funding from the National Science Foundation is expected to support the modification and deployment of the radar. The AN/TPQ-37 Firefinder radar is a modern mobile, phased array, pulse doppler radar and will be modified so it can be used as an instrument for meteorological research. Funding from the Office of Naval Research is anticipated to support development of at sea capabilities for the Fleet.



The AN/TPQ-37 Firefinder Radar.



The AN/MPQ-64 Sentinel Radar.

## FACULTY AWARDS

### NPS FACULTY MEMBER RECOGNIZED FOR DISTINGUISHED CIVILIAN SERVICE

The Navy Distinguished Civilian Service Award was presented to Professor **Rudolf Panholzer**, Dean of Science and Engineering and Chair of the Space Systems Academic Group, for distinguished service as a Professor at the Naval Postgraduate School since January 1964, and as the Chairman of the Space Systems Academic Group, involved since its inception in July 1982. During this period Dr. Panholzer distinguished himself by developing NPS into a national center of excellence in space education and research demonstrated by landmark projects such as CHALLENGE ATHENA, and culminating in the launch of the Petite Amateur Navy Satellite (PANSAT) from the Space Shuttle DISCOVERY on 29 October 1998.

The development of PANSAT was the direct result of Dr. Panholzer's leadership and drive involving 51 students' Masters-level theses over the period March 1989 until the satellite was launched during STS-95. His vision resulted not only in a revolutionary first in satellite spread-spectrum communications, but also an amazing educational breakthrough - a real space vehicle and communications payload, on orbit. This was a monumental task for a small group of educators and researchers independent of national space installations.

Dr. Panholzer's selfless leadership and drive are universally lauded by his many students and faculty who hold him in the



**Professor Rudolf Panholzer (right) with the Honorable H. Lee Buchanan, Assistant Secretary of the Navy for Research, Development and Acquisitions, tour the "PANSAT" Lab during a recent visit.**

highest regard and deepest affection, which is the ultimate tribute. His undying loyalty and inspiring dedication to duty reflect great credit upon himself and the Naval Postgraduate School which is in keeping with the highest traditions of the Department of the Navy.

### DISTINGUISHED PROFESSOR EMERITUS RECEIVES ART STEIN MEMORIAL CUP FOR EXCELLENCE

Distinguished Professor Emeritus Professor **Robert Ball** received the DOT&E/LFT "Art Stein Memorial Cup for Excellence" at the Live Fire Test and Evaluation National Workshop held at the University of Texas in Austin on 8-12 May 2000. Professor Ball has been a major force in efforts to establish survivability as a design discipline for many years. The Joint Technical Coordinating Group on Aircraft Survivability (JTTCG/AS), established in 1971 as a result of the very large number of U.S. aircraft lost in Vietnam, had a primary goal of establishing aircraft combat survivability (ACS) as a design discipline. Dr. Ball believed that in order for combat survivability to become an accepted design discipline, an educational program must be developed. In 1977, while on the faculty of the Department of Aeronautics and Astronautics at the Naval Postgraduate School (NPS), he developed the first combat survivability course ever to be offered at an educational institution as part of their regular curriculum. Survivability is now a part of the Educational Skill Require-

ments for the NPS Aeronautical Engineering Curriculum.

Professor Ball has written the only textbook on survivability, *The Fundamentals of Aircraft Combat Survivability Analysis and Design*. His textbook was sponsored by the JTTCG/AS and published in 1985 by the American Institute of Aeronautics and Astronautics (AIAA) as part of their Educational Series. AIAA has sold approximately 10,000 copies (with over 3000 going to DoD), and the book has been a 'best seller' for the AIAA for many years. The book has been widely recognized as a major factor in formally establishing survivability as a design discipline and has been used throughout the survivability design, analysis, and test community, both government and industry, as well as in educating program managers and other high level acquisition community members.

Professor Ball retired from the Naval Postgraduate School in November 1998 as a Distinguished Professor Emeritus. He works as a consultant and is continuing work on the 2<sup>nd</sup> edition of his survivability textbook for the JTTCG/AS.

## FACULTY NEWS

### AERONAUTICS AND ASTRONAUTICS

Von T.W. Backstrom, G.V. Hobson, B. Grossman, and R.P. Shreeve, "Numerical Analysis of a CFD Designed Compressor Stage," 36<sup>th</sup> AIAA Conference, Huntsville, AL, July 2000.

J. Barnaby and R.W. Duren, "Development of a Standard Interface for a New Generation of Miniature Stores," *Proceedings of the 18<sup>th</sup> Digital Avionics Systems Conference*, 1999.

R.W. Duren, "Development of a Small Rotary-Wing Autonomous Vehicle," *Proceedings of the 18<sup>th</sup> Digital Avionics Systems Conference*, 1999.

R.W. Duren, E.R. Wood, and M.A. Couch, "NPS Research on Vortex Ring State," Rotocraft Aeromechanics Workshop, Patuxent River, MD, 18-19 July 2000.

R.W. Duren, E.R. Wood, and M.A. Couch, "NPS Vortex Ring State Definition and Safety Data Review," Rotocraft Aeromechanics Workshop, Patuxent River, MD, 18-19 July 2000.

S. Hendricks and R.W. Duren, "Using OPNET to Evaluate Fibre Channel as an Avionics Interconnection System," *Proceedings of the 19<sup>th</sup> Digital Avionics Systems Conference*, 2000.

G.V. Hobson, D.J. Hansen, D.G. Schnorenberg and D.V. Grove, "Effect of Reynolds Number on Separation Bubbles on Controlled-Diffusion Compressor Blades in Cascade," *AIAA Journal of Propulsion and Power*, 2000.

K.D. Jones, J.C.S. Lai, I.H. Tuncer, and M.F. Platzer, "Experimental and Computational Investigations of Flapping Foil Propulsion," First International Symposium on Aqua Bio-Mechanisms, ISABMEC 2000, Honolulu, Hawaii, 27-30 August 2000.

K.D. Jones, T.C. Lund, and M.F. Platzer, "Experimental and Computational Investigation of Flapping-Wing Propulsion for Micro-Air Vehicles,"

*Proceedings of the Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers*, Notre Dame, IN, 5-7 June 2000.

M.F. Platzer and K.D. Jones, "The Unsteady Aerodynamics of Flapping Foil Propellers," 9<sup>th</sup> International Symposium on Unsteady Aerodynamics, Aeroacoustics and Aeroelasticity of Turbomachines and Propellers, Lyon, France, 4-8 September 2000.

I.H. Tuncer and M.F. Platzer, "Computational Study of Flapping Airfoil Aerodynamics," *Journal of Aircraft*, Vol. 37. No. 3, pp. 514-520, May-June 2000.

D. Varnes and R.W. Duren, "Pilot and Crew Aids for the H-60 Helicopter," *Proceedings of the 18<sup>th</sup> Digital Avionics Systems Conference*, 1999.

S. Weber and M.F. Platzer, "Numerical Analysis of the Stall Flutter Characteristics of the Buffum Cascade," 9<sup>th</sup> International Symposium on Unsteady Aerodynamics, Aeroacoustics and Aeroelasticity of Turbomachines, Lyon, France, 4-8 September 2000.

E.R. Wood and R.W. Duren, "An Onboard Warning System to Prevent Hazardous 'Vortex Ring State' Encounters," 26<sup>th</sup> European Rotocraft Forum, Hague, Netherlands, 26-29 September 2000.

### COMPUTER SCIENCE

V. Berzins, M. Shing, Luqi, M. Saluto, and J. Williams, "Object-Oriented Modular Architecture for Ground Combat Simulation," *Proceedings of the 2000 Command and Control Research and Technology Symposium*, Monterey, CA, 26-28 June 2000.

D.A. Brunstad and J.B. Michael, "Increasing Interoperability by Converging Services in Constraint-Based Routing Networks," *Proceedings of the IEEE Eighth International Conference on Software, Telecommunications and*

*Computer Networks*, October 2000.

Ngom Cheng, V. Berzins, Luqi, and S. Bhattacharya, "Automated Generation of Wrappers for Interoperability," 2000 Command and Control Research and Technology Symposium, Monterey, CA, July 2000.

L.T. Gaines and J.B. Michael, "Trust Management in OLAP Tools," *Proceedings of the IFIP Working Group 11.3 Working Conference on Database Security*, September 2000.

L. Grewe, N.C. Rowe, and W. Baer, "AERICOMP: An Aerial Photo Comparison System," SPIE Signal Processing, Sensor Fusion, and Target Recognition IX Conference, June 2000.

G.K. Hunter and N.C. Rowe, "Software Design for a Fault-Tolerant Communications Satellite," Command and Control Research and Technology Symposium, Monterey, CA, June 2000.

D.J. Ingram, N.C. Rowe, and H.S. Kremer, "Distributed Intrusion Detection for Computer Systems Using Communicating Agents," Command and Control Research and Technology Symposium, Monterey, CA, June 2000 (Best Paper Award).

C.E. Irvine and T. Levine, "Quality of Security Service," New Security Paradigms Workshop, Cork, Ireland, September 2000.

Luqi, V. Berzins, M. Shing, N. Nada, and C. Eagle, "Computer Aided Prototyping System (CAPS) for Heterogeneous Systems Development and Integration," *Proceedings of the 2000 Command and Control Research and Technology Symposium*, Monterey, CA, 26-28 June 2000.

Luqi, V. Berzins, M. Shing, and N. Nada, "Evolutionary Computer Aided Prototyping System (CAPS)," *Proceedings of the TOOLS USA 2000 Conference*, Santa Barbara, CA, 30 July-3 August 2000.

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## FACULTY NEWS

--continued from page 33

N. Nada and Luqi, "Automated Prototyping Toolkit," 22<sup>nd</sup> International Conference on Software Engineering (ICSE 2000), Second International Symposium on Constructing Software Engineering Tools (COSET 2000), Limerick, Ireland, 4-11 June 2000.

N. Nada and Luqi, "Software Evolution Approach for the Development of Command and Control Systems," 2000 Command and Control Research and Technology Symposium, Monterey, CA, 26-28 June 2000.

N. Nada, Luqi, D. Rine, and E. Damiani, "A Knowledge-Based System for Software Reuse Technology Practices," 22<sup>nd</sup> International Conference on Software Engineering (ICSE 2000), Third International Workshop on Intelligent Software Engineering WISE3, Limerick, Ireland, 4-11 June 2000.

N. Nada, Luqi, David Rine, and Ernesto Damiani, "A Knowledge-Based Adaptive Distance Learning System for Software Reuse Technology," Twelfth International Conference on Software Engineering and Knowledge Engineering SEKE 2000, Chicago, IL, 6-8 July 2000.

N. Nada, Luqi, D. Rine, and K. Jaber, "Product Line Stakeholder Viewpoint and Validation Models," 22<sup>nd</sup> International Conference on Software Engineering (ICSE 2000), Workshop on Software Product Lines: Economics, Architectures, and Implications, Limerick, Ireland, 4-11 June 2000.

J. Nogueira and Luqi, "Surfing the Edge of Chaos: Applications to Software Engineering," 2000 Command and Control Research and Technology Symposium, Monterey, CA, 26-28 June 2000.

J. Nogueira, Luqi, and V. Berzins, "A Formal Risk Assessment Model for Software Evolution," 12<sup>th</sup> International

Conference on Software Engineering and Knowledge Engineering, Chicago, IL, 6-8 July 2000.

J. Nogueira, Luqi, and V. Berzins, "Risk Assessment in Software Requirement Engineering," 5<sup>th</sup> World Conference on Integrated Design & Process Technology, Dallas, TX, 4-8 June 2000.

J. Nogueira, Luqi, and S. Bhattacharya, "A Risk Assessment Model for Software Prototyping Projects," 11<sup>th</sup> IEEE International Workshop on Rapid System Prototyping, Paris, France, 21-23 June 2000.

J. Nogueira, Luqi, V. Berzins, and N. Nada, "A Formal Risk Assessment Model for Software Evolution," 22<sup>nd</sup> International Conference on Software Engineering (ICSE 2000), 2<sup>nd</sup> International Workshop on Economics-Driven Software Engineering Research (EDSER-2), Limerick, Ireland, 4-11 June 2000.

S.J. Robin and C.E. Irvine, "Analysis of the Intel Pentium's Ability to Support a Secure Virtual Machine Monitor," *Proceedings of the 9<sup>th</sup> USENIX Security Symposium*, Denver, CO, August 2000.

N.C. Rowe, "A Digital Library of Aerial Photographs Supporting Change Analysis," poster presentation, ACM Digital Libraries 2000, San Antonio, TX, June 2000.

D.L.L. Sicuro and N.C. Rowe, "Automatic Generation of Best Emergency Routes and Procedures on a Brazilian Frigate," Command and Control Research and Technology Symposium, Monterey, CA, June 2000.

### DEFENSE RESOURCE MANAGEMENT INSTITUTE

P.C. Frederiksen was invited to lecture at the Army Headquarters of

the Republic of China by MGEN Cheang, Yun-Ping (SIDMC 99 graduate), Chief, Weapons Acquisition Planning Service, 3 May 2000. The lecture discussed the effects of defense spending on economic growth with special emphasis on South-East Asia.

J. Martinez-Vazquez and R.M. McNab, "The Tax Reform Experiment in Transitional Economies," *National Tax Journal*, Vol. 53, No. 2, 2000.

F. Melese, "Strategic Investment in Military Education: An Economic Perspective," *Phalanx*, June 2000.

F. Melese and J. Palmore, "Ballistic Missile Defense: Protection or Placibo," *Defense Analysis*, Vol. 16, No. 1, 2000.

### ELECTRICAL AND COMPUTER ENGINEERING

R. Ives and N. Magotra, "Lossless Compression of Waveform Data Using Multiple-Pass Adaptive Filtering," IEEE International Geoscience and Remote Sensing Symposium (IGARSS), Honolulu, HI, July 2000.

R. Janaswamy, "Spatial Diversity in Wireless Communications," *Handbook on Antennas in Wireless Communications*, CRC Press, L. Godara, ed.

J. Knorr, "AN/MPQ-64 Radar Application to Severe Storm Research," Ground-Based Mobile Instrumentation Workshop, Boulder, CO.

P.E. Pace, *Advanced Techniques for Digital Receivers*, Artech House, Inc., July 2000.

P.E. Pace, S.A. Bewley, and J.P. Powers, "Fiber Lattice Accumulator Design Considerations for Optical Sigma-Delta Analog-to-Digital Converters," *Optical Engineering*, Vol. 39, No. 6, June 2000.

P.E. Pace, D. Styer, and B. Ringer, "An Optimum SNS-to-Binary Conversion Algorithm and Pipelined Field

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## FACULTY NEWS

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Programmable Logic Design," *IEEE Transactions on Circuits and Systems-II: Analog and Digital Signal Processing*, Vol. 47, No. 8, August 2000.

E.N. Pugh, Jr., N. Engheta, M.P. Rowe, and J.S. Tyo, "Method of Using Polarization Differencing to Improving Vision," U.S. Patent No. 5,975,702, 2 November 1999.

J.S. Tyo, "Improvement of the Point Spread Function in Scattering Media by Polarization Difference Imaging," *Journal of the Optical Society of America*, A 17, 1-10, January 2000.

J.S. Tyo, "Noise Equalization in Stokes Paramete Images Obtained Using Variable Retardance Polarimetry," *Optics Letter* 25, 2000.

J.S. Tyo, "Considerations in Polarimeter Design," *SPIE*, Vol. 4133, *Polarization Measurement and Analysis III*, D.B. Chenault and D.L. Goldstein, eds.

J.S. Tyo, "Optimal Feeds for 4-Arm IRAs," *Ultra-Wideband, Short-Pulse Electromagnetics 5*, P.D. Smith and D.M. Parkes, eds.

J.S. Tyo, "Maximization of Information Content in Polarimetric Measurements," 2000 IEEE/AP-S International Symposium, Salt Lake City, UT, 16-20 July 2000.

Prof. J.S. Tyo was named as a member of an Air Force Office of Scientific Research Star Team for World-Class Research in Ultra-Wideband Electromagnetic Systems, April 2000.

J.S. Tyo and C.J. Buchenauer, "Compact Sensors for Time-Domain Measurements," EUROEM 2000, Edinburgh, Scotland, 30 May-2 June 2000.

J.S. Tyo and R.C. Olsen, "Development of an Invariant Display Strategy for Spectral Imagers," *SPIE*, Vol. 4132, *Imaging Spectrometry VI*,

M.R. Descour and S.S. Shen, eds.

J.S. Tyo, J. Robertson, and R.C. Olsen, "Statistics of Target Spectra in HSI Scenes," *SPIE*, Vol. 4132, *Imaging Spectrometry VI*, M.R. Descour and S.S. Shen, eds.

J.S. Tyo and T.S. Turner, "Use of a Variable Retardance, Spatial Fourier Transform Imaging Device to Obtain Spectropolarimetric Images for Remote Sensing," 1999 Optical Society of America Annual Meeting, San Jose, CA, 29 September-3 October 2000.

X. Yun, E.R. Bachmann, and Suat Arslan, "An Inertial Navigation System for Small Autonomous Underwater Vehicles," *Proceedings of 2000 IEEE International Conference on Robotics and Automation*, San Francisco, CA, April 2000.

### INFORMATION SYSTEMS

N.F. Schneidewind, "Measuring and Evaluating Maintenance Process Using Reliability, Risk, and Test Metrics," *IEEE Transactions on Software Engineering*, Vol. 25, No. 6, November/December 1999.

N.F. Schneidewind, "Software Maintenance," *Encyclopedia of Computer Science*, April 2000.

N.F. Schneidewind, "Software Quality Control and Prediction Model for Maintenance," *Annals of Software Engineering*, April 2000.

N.F. Schneidewind, "The Ruthless Pursuit of the Truth About COTS," *Proceedings of the North Atlantic Treaty Organization, Commercial Off-the-Shelf Products in Defense Applications*, Brussels, Belgium, 3-5 April 2000.

Prof N.F. Schneidewind has been named Distinguished Visiting Program Speaker by the IEEE Computer Society. He has also been accepted as a distinguished speaker in the IEEE Computer Society Chapters and Tutorials Program.

N.F. Schneidewind, "Developing the Next Generation IEEE Dependability Standard," Software Technology Conference, Salt Lake City, UT, 4 May 2000.

N.F. Schneidewind, Tutorial Notes, "A Roadmap to Distributed Client-Server Software Reliability Engineering," Quality Week 2000, San Francisco, CA, 30 May 2000.

### MATHEMATICS

H. Fredricksen, "Symmetric Sum-Free Partitions and Lower Bounds for Schur Numbers," *Electronic Journal of Combinatorics*, Article R32, Vol. 7 (1), 2000.

T. Fukushima and B. Neta, "Obrechhoff Versus Super-Implicit Methods for the Solution of First and Second Order Initial Value Problems," *International Journal of Computers and Mathematics with Applications*.

### MECHANICAL ENGINEERING

Prof C. Calvano has been invited by the Royal Military College of Science (RMCS), United Kingdom, to be a Visiting Professor in their Systems Engineering Master of Science Degree Program. Prof. Calvano has also been involved in a major rewrite of *Naval Engineering and American Seapower*.

A. Fox and M. Saunders, "Structure Factor Measurement by Convergent Beam Electron Diffraction," ANZIP 24<sup>th</sup> Conference on Condensed Matter Physics, Wagga Wagga, New South Wales, Australia, February 2000.

A. Fox, "Modern Methods in Transmission Electron Microscopy," University of Sydney and University of Technology, Sydney, March 2000; Melbourne University, RMIT University and Monash University, Melbourne; Australian National University and Australian Defense

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Forces Academy, Canberra, April 2000; University of Western Australia, Perth, May 2000; and University of Queensland, Brisbane, Australia, June 2000.

**T. Sarpkaya**, "Time-Dependent Flow About Rigid and Perforated Bodies," International Congress of Theoretical and Applied Mechanics, Marseille, France, 11-16 June 2000.

**T. Sarpkaya**, "High Speed Laser-PIV Imaging for the Eulerian-Lagrangian Measurement and Visualization of Spray on Wall-Bounded Jets," International Congress on Liquid Atomization and Spray (ICLASS), Pasadena, CA, 17-22 September 2000.

**T. Sarpkaya**, "Characterization of Free Surface Structures on High-Speed Liquid Jets," International Congress on Liquid Atomization and Spray (ICLASS), Pasadena, CA, 17-22 September 2000.

### NATIONAL SECURITY AFFAIRS

**R. Looney**, "Internal and External Constraints on Saudi Arabian Economic Growth: The Role of Defense Expenditures and Remittances," *The Political Economy of Middle East Peace*, J.W. Wright, ed, 2000.

Prof. **D. Porch's** paper, "The Taiwan Strait Crisis of 1996: Strategic Implications for the United States Navy," published in the Summer 1999 issue of *The Naval War College Review* was selected as the second-place winner of the Hugh G. Nott Prize for the best articles of the 1999 published year. The selection committee, formed of members of the Naval War College faculty, cited Porch's article as, "a penetrating analysis of a topic of vital operational interest to the naval service." These awards are made in memory of Captain Hugh G. Nott,

U.S. Navy, who made major contributions to the academic and research life of the Naval War College. At present, Porch is finishing a study on military/media relations for USAID.

**D.S. Yost**, "European Security and Defense Identity (ESDI) and the European-American Capabilities Gap," Transformation of NATO and the Question of European Unity Conference, Seattle, WA, 5 May 2000.

**D.S. Yost**, "Alternative Futures for NATO-Russia Relations," Post-Yeltsen Russia Conference, Camberley, England, 27 June 2000.

### OCEANOGRAPHY

A.Yu Benilov and **L.N. Ly**, "Modeling of Surface Waves Breaking Effects in the Ocean's Upper Layer," *Mathematical and Computer Modeling*, 2000.

**P.C. Chu**, "P-Vector Spirals and Determination of Absolute Velocities," *Journal of Oceanography*, 56, 2000.

**P.C. Chu**, "Toward Accurate Coastal Ocean Modeling," Advances in Mathematical Modeling of Atmosphere and Ocean Dynamics, International Union of Theoretical and Applied Mechanics, Limerick, Ireland, 2-7 July 2000.

**P.C. Chu** and **C.W. Fan**, "A Staggered Three-Point Combined Compact Difference Scheme," *Mathematical and Computer Modeling*, 32, 2000.

**P.C. Chu**, **C.W. Fan**, and **W.T. Liu**, "Determination of Sub-Surface Thermal Structure from Sea-Surface Temperature," *Journal of Atmospheric and Oceanic Technology*, 17, 2000.

**P.C. Chu** and **R.F. Li**, "South China Sea Isopycnal Surface Circulations," *Journal of Physical Oceanography*, 30, 2000.

**P.C. Chu** and **S.H. Lu**, "A Coastal Atmosphere and Ocean Coupled System (CAOCS) for Data Assimilation and Prediction," Advances in

Mathematical Modeling of Atmosphere and Ocean Dynamics, International Union of Theoretical and Applied Mechanics, Limerick, Ireland, 2-7 July 2000.

**P.C. Chu**, **J.M. Veneziano**, and **C.W. Fan**, "Response of the South China Sea to Tropical Cyclone Ernie, 1996," *Journal of Geophysical Research*, 105, 2000.

**A.F. Garcez Faria**, **E.B. Thornton**, **T.C. Lippmann**, and **T.P. Stanton**, "Undertow Over a Barred Beach," *Journal of Geophysical Research*, 105 (C7), 2000.

**P. Luong**, **C.P. Breshears**, and **L.N. Ly**, "Dual-Level Parallelism Improves Load-Balance in Coastal Ocean Modeling," DoD HPC Users Group Conference, Albuquerque, NM, 5-7 June 2000.

**P. Luong**, **C.P. Breshears**, and **L.N. Ly**, "Dual-Level Parallelism and Multi-Block Grids in Coastal Ocean Circulation Modeling," 13th International Conference on Parallel and Distributed Computing Systems, Las Vegas, NV, 8-10 August 2000.

**P. Luong**, **C.P. Breshears**, and **L.N. Ly**, "Dual-Level Parallelism and Multi-Block Grids in Coastal Ocean Circulation Modeling," *13th International Conference on Parallel and Distributed Computing Systems Proceedings*, Las Vegas, NV, 8-10 August 2000.

**L.N. Ly**, **W.P. Connor**, and **J.D. Paduan**, "A Barotropic Simulation of Semi-Diurnal and Diurnal Tides for the Monterey Bay Region," *Coastal Dynamics and Estuaries in Hydraulic Engineering Software EIII*, W.R. Blain and C.A. Brebbia, eds, 2000.

**L.N. Ly** and **R.W. Garwood, Jr.**, "Numerical Modeling of Wave-Enhanced Turbulence in the Oceanic Upper Layer," *Journal of Oceanography*, Vol. 56, 2000.

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## FACULTY NEWS

--continued from page 36

### PHYSICS

**X.K. Maruyama**, "Observations Concerning UXO Removal Efforts on the Former Fort Ord," 5<sup>th</sup> Unexploded Ordnance and Range Remediation Conference, EUROEM, Edinburgh, Scotland, 29 May–3 June 2000.

### SYSTEMS MANAGEMENT

**Prof. M. Eitelberg** received the "Robert M. Yerkes Award" for his significant contributions to military psychology by a non-psychologist. The award comes from Division 19 (Military Psychology) of the American Psychological Association, and was presented at the APA's annual convention in Washington, DC, 6 August 2000.

**K.R. Gue**, "Optimizing Picking Waves for a Defense Distribution Depot," NPS Technical Report, NPS-SM-00-007, May 2000.

**S.P. Hocevar**, "A Preliminary Analysis of the 1999 USMC Web-Based Exit Survey," NPS-SM-00-008, June 2000.

**Prof. S.P. Hocevar** co-facilitated a "Table-Top" Wargame for Effects-Based Operations (EBO), involving over 30 participants. She also acted as a member of the observation team comprised of both researchers from the Adaptive Architectures for Command and Control (A2C2) project and members from the NPS Institute for Joint Warfare Analysis (IJWA). Participants included representatives from the COMCARGRU3 (CCG3) who were "rehearsing" both EBO and Command and Control issues in preparation for the Global Wargame conducted at the Naval War College in August. Additional participants from the Naval Warfare Development Command (NWDC) were field-testing a draft of

documentation on EBO, a key concept to be tested at Global.

**Prof. S.P. Hocevar** represented NPS's Institute for Joint Warfare Analysis and the A2C2 Research Team, as an observer at the Global Wargame 2000, conducted at the Naval War College, Newport, RI, 15-24 August 2000. The focus of the team was on gathering data related to command and control processes, organizational adaptation, decision making, and the impact of information technology tools. Over 400 officers from all services participated in Global, and preliminary findings from the A2C2 team were included in the CNO and Flag Officer briefings conducted at the close of the wargame.

**P. Hogan, J. Hughes, S. Mehay, and M. Cook**, "Enlistment Supply at the Local Level," NPS Technical Report, NPS-SM-00-004, May 2000.

**G. Fann-Thomas**, "Sages, Soothsayers, and Scholars: A Look at the Future and Implications for Business/Managerial Communication," Western Regional Association for Business Communication, Fullerton, CA, 10-12 May 2000.

**L.R. Jones**, "Management Control and Best Practices in the Public Sector: The Motivational Perspective," *Proceedings of the Roman Forum 2000*, Rome, Italy, May 2000.

**D.F. Matthews and M.E. Nissen**, "Software Acquisition Lessons Learned through Student Thesis Research," *Army AL&T*, May-June 2000.

**A.W. McMasters**, "A Preliminary Evaluation of a Readiness-Based Repairable Item Inventory Model for the U.S. Navy," NPS Technical Report, NPS-SM-00-006, May 2000.

**M.E. Nissen**, "Agent Supply Chain Dis/Re-Intermediation," IFIP Working Group 7.6 Workshop on Virtual Environments for Advanced Modeling,

Monterey, CA, August 2000.

**M. Nissen and J. Espino**, "Knowledge Process and System Design for the Coast Guard," *Knowledge and Process Management Journal*, 7:3, September 2000.

**M. Nissen, M. Kamel, and K. Sengupta**, "A Framework for Integrating Knowledge Process and System Design," *Information Strategy: The Executive's Journal*, 16:4, Summer, 2000.

**M. Nissen and K. Snider**, "U.S. Defense Acquisition Research Program," *Proceedings, First PMI Research Conference*, Paris, France, June 2000.

**N.C. Roberts and J. Menker**, "Strategic Management in the Federal Government: Necessary and Sufficient Elements," *Handbook of Strategic Management*, Jack Rabin, Gerald Miller and W. Bartley Hildreth, eds., , 2000.

**T. Sammis, D. Wilkinson, S. Mehay, and K. Gue**, "Application and Assessment of the Recruiting Station Location Evaluation System," NPS Technical Report, NPS-SM-00-003, May 2000.

**K.F. Snider**, "Expertise or Experimenting? Pragmatism and American Public Administration, 1920-1950," *Administration and Society*, Vol. 32, No. 3, July 2000.

**K.F. Snider**, "Rethinking Public Administration's Roots in Pragmatism: The Case of Charles A. Beard," *The American Review of Public Administration*, Vol. 30, No. 2, June 2000.

**K.F. Snider**, "Acquisition CENTRALL: Getting the Word Out on Acquisition Lessons Learned," *Army AL&T*, May-June 2000.

**K.F. Snider**, "Response to Stever and Garrison," *Administration and Society*, Vol. 32, No. 4, September 2000.

# RESEARCH OVERVIEW

## MISSILE DEFENSE RESEARCH, *continued from page 5*

behavior of new military powers indicate about the theories that explain military doctrines and command and control systems?

### TBMD and BMD Used as Case Studies for Investigating Frameworks for Information Modeling

Associate Professor J. Bret Michael and LT Sheila Smith, USN (June 2000) have been investigating frameworks for information modeling in the context of modeling large distributed systems. They chose to use Theater Ballistic Missile Defense (TBMD) and Ballistic Missile Defense (BMD) as case studies for evaluating promising frameworks.

The scope of work to date has been to evaluate existing frameworks in terms of how well they support the detection and resolution of inconsistency in policy, requirements, and specifications. One such framework, known as the Reference Model of Open Distributed Processing (RM-ODP), has been explored. RM-ODP provides for modeling a system from multiple viewpoints, with each viewpoint corresponding to a different level of abstraction of the system under study. Confirming evidence has been found for their hypothesis that identifying inconsistencies regarding the interoperability amongst the subsystems of BMD or TBMD will necessitate the use of multiple viewpoints. In the NPS study of BMD, it was found that firm conclusions could not be made about the existence of inconsistencies regarding inoperability until the system is modeled and then analyzed using the lower level viewpoints.

### Project KillTEL: An Unmanned Air Vehicle Ballistic Missile Launcher Detection and Destruction System

Past efforts to find and destroy mobile missile launchers have resulted in mixed success, and have led to the development of anti-ballistic missile systems designed to destroy incoming missiles. In Project KillTEL, Associate Professors Richard Howard, Isaac Kaminer, I. Michael Ross, and Distinguished Professor David Netzer of the

Department of Aeronautics and Astronautics, designed an architecture that exploited the research of faculty from their own department as well as the Departments of Electrical and Computer Engineering, Operations Research, and Systems Management. The proposal was to demonstrate that relatively simple, off-the-shelf, current-technology sensors can be combined in a ground-sensor/unmanned-air-vehicle/satellite/missile system to detect the movement of mobile ballistic missile launchers and, upon authority, launch a small inexpensive supersonic tactical missile from the unmanned aerial vehicle (UAV) for launcher destruction. Data fusion of sensors from space, high altitude UAVs and ground would serve as the “eyes” while a lethal UAV with a missile payload would serve as the launch platform. The missile design consisted of a small cheap “Plexiglas” supersonic missile while the avionics would be a

standard GPS-IMU integrated unit. Parts of the project that were completed were a study of appropriate ground sensors, test firing of the missile, and the design of a satellite system for the desired coverage.

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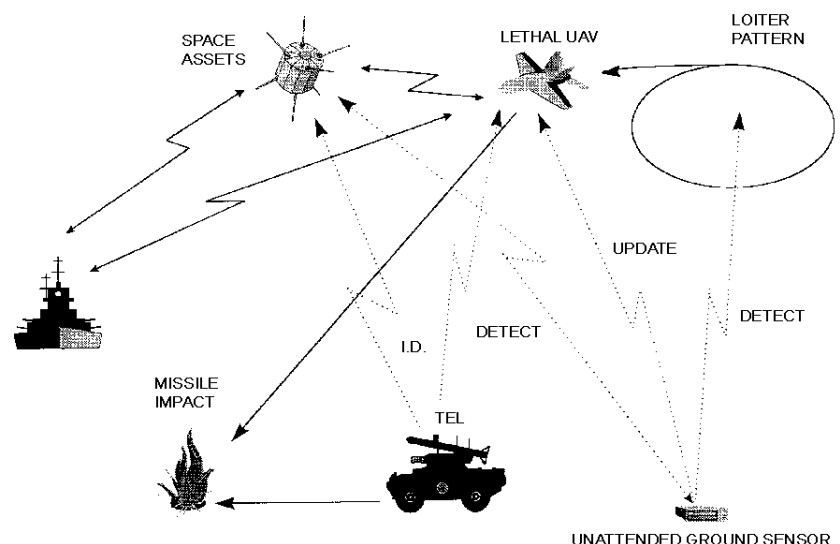
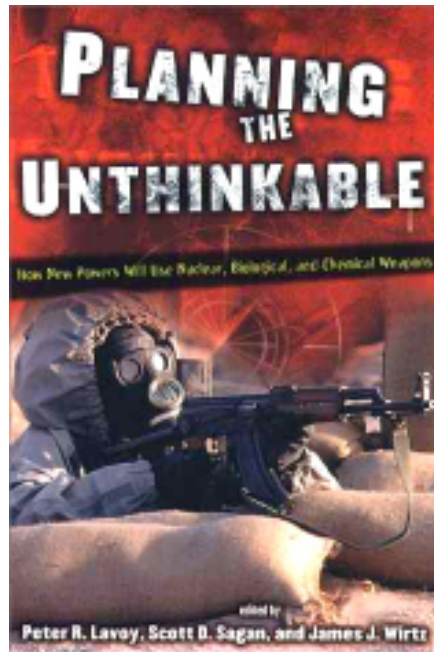


Figure 1. Overall System Structure.

## RESEARCH OVERVIEW

### MISSILE DEFENSE RESEARCH, *continued from page 38*

#### Tracking and Killing Mobile Targets Using Precision Guided Munitions

Associate Professor **Russ Duren** of the Department of Aeronautics and Astronautics and several thesis students are working on problems related to TBMD. **CDR Randolph L. Mahr, USN**, is investigating the application of precision-guided munitions against moving targets, such as mobile missile launchers. His thesis is tentatively titled, "Issues and Applications when Using GPS-guided Air-to-Ground Weapons Against Moving Targets." The goal of this thesis is to develop an executable model of a hypothetical sensor-to-weapon real-time targeting system for the Joint Standoff Weapon. The model will be used to perform error and timing analyses to fully characterize the system's performance. The tool chosen for the modeling task is Statemate Magnum from I-Logix, Inc. The tool should provide the capability of producing not just a simulation model, but an executable specification for the sensor-to-weapon system. This specification can serve as the template for a wide range of sensor-to-weapon systems, allowing new systems to be quickly modeled and compared.

**LCDR Dean A. Wilson, USN**, is investigating Multiple Source Integration/Data Fusion (MSI/DF) techniques that can be used on aircraft such as the E-2C Hawkeye. His thesis is tentatively titled, "Analysis of Multiple Source Integration (MSI) Techniques and Their Contributions to Probabilistic Combat Identification (CID)." Although the research is not specifically directed at identification and tracking of missiles,

that is one of the applications of the techniques under investigation.

#### Atmospheric Optical Turbulence

Solar heating, pressure variations, temperature gradients and wind shear all interact to produce turbulent flow within the atmosphere. Small temperature and density fluctuations carried by the turbulent air produce subtle phase distortions in electromagnetic waves traveling through the atmosphere. At optical wavelengths these effects accumulate over long paths of several kilometers to the point where they seriously degrade our ability to focus laser energy onto a target or blur the image of a target of interest.

For some systems such as the U.S. Airborne Laser Program, part of the Theater Ballistic Missile Defense effort, atmospheric optical turbulence is a primary limitation to the ability to destroy missiles at long ranges. Knowledge of severe detrimental events such as the jet stream is essential for effective operational deployment of aircraft in the threat area.

Professor **Donald Walters**, Department of Physics, and Research Assistant Professor **Douglas Miller**, Department of Meteorology, with assistance from Associate Professor **Wendell Nuss** of the Department of Meteorology, have adapted the U.S. Navy COAMPS (Coupled Ocean Atmosphere Meteorological Prediction System Model) developed by NRL Monterey, and used by Fleet Numerical Oceanography and Meteorology Center (FNMOC), so that it can

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### COMBAT SYSTEMS CURRICULUM INTEGRATES STRATEGIC MISSILE DEFENSE

A two course sequence, Combat Systems Requirements and Design (SE2020) and Combat System Project Integration (SE4021), requires students to put to use their technical graduate education in a systems engineering solution to a current operational problem. The course sequence develops the requirements and investigates the conceptual systems design for combat systems of contemporary interest. The operational problem selected for detailed definition and solution is to be at the limits of today's technology and operational arts. Examples include defense against tactical ballistic missiles, zero-collateral-damage counter-battery combat systems, and shallow water anti-submarine and mine warfare autonomous systems. The general scope of the systems project is determined in the first quarter

through the examination and discussion of current fleet requirements and plausible application of leading edge technology to meet the requirement.

Subsequent quarters involve seminars, guest lectures, laboratory visits, and discrete problems and subprojects integrated into the courses of the curriculum. The final SE4021 course integrates the results of the subsystem studies begun earlier into the design of a combat system aimed at solving the operational problem. The resulting solution addresses the threat and operational environment; the assignment of tasks to subsystems components; the performance of the system in terms of its coverage, fire power, reaction time, and response to countermeasures; and costs. The results are presented to an experienced external review group.

# RESEARCH OVERVIEW

## MISSILE DEFENSE RESEARCH, *continued from page 39*

provide good estimates of optical turbulence and laser propagation conditions in the atmosphere. To accomplish this they had to modify the turbulence closure assumptions in the COAMPS model so it could work correctly in the free atmosphere and stratosphere, and develop an optical turbulence parameterization scheme.

Running the COAMPS mesoscale weather model on the High Performance Computing Machines located at the Naval Oceanographic Office, Stennis Space Center, Mississippi, and the U.S. Army Engineer Research Center Laboratories, Vicksburg, Mississippi, they are able to predict atmospheric

turbulence conditions 6-12 hours beyond the initial starting conditions. These predictions agree well with aircraft and balloon measurements of turbulence collected by NPS in CONUS and the U.S. Air Force in potential threat areas.

NPS model results were included as a significant new capability during a critical program review presented by the ABL SPO to Dr. Hans Mark, Director of Defense Research and Engineering during the spring of this year. Because of the NPS success, the U.S. Air Force Research Laboratory has initiated their own effort to model optical turbulence within the atmosphere.

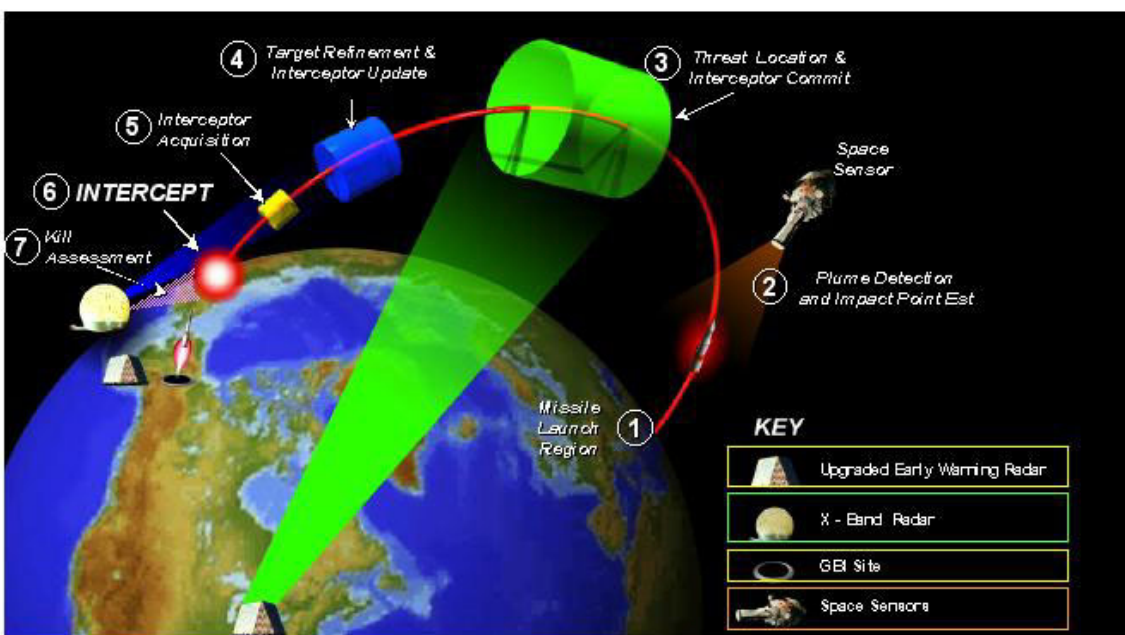
## AN INVESTIGATION INTO ALTERNATIVE NATIONAL MISSILE DEFENSE SCHEMES

LT James Kalowsky, USN  
LT Victor Lake, USN  
LT Stephen Meade, USN  
LT Robert Thompson, USN

Ballistic missile defense is an important and controversial topic with no standard operational procedures in place today that could neutralize a ballistic missile threat. The issue of how to defend against an inbound, rouge state, nuclear ballistic missile was studied with focus on the two leading kill

mechanism options: nuclear and hit-to-kill. National Missile Defense (NMD) plans of the past and future were reviewed. Logistics and timeline problems were investigated and resulted in a likely engagement scenario. The hit-to-kill option is a precision problem that is presently being worked on by the DoD, however it is still in the early stages of development. The nuclear option was investigated as to whether it could meet the requirements of ensuring destruction of an inter-continental ballistic missile in the near future. At the higher latitudes expected for the engage-

ment, the effects of a nuclear environment in the exo-atmosphere were studied, as well as the effects on spacecraft and satellite electronics. Also, the short-term degradation or blackout of sensor systems was studied, with particular interest given to early warning systems. Conclusions were drawn from the comparison between the hit-to-kill approach and the nuclear option.



NMD Engagement CONOPS

## FEATURED PROJECT

### JP-10/AEROSOL FOR PULSE DETONATION APPLICATIONS, *continued from page 7*

Due to the increased difficulty of detonating a fuel/air mixture, a small (pilot) combustor which operated on JP-10 and oxygen was used to generate a very strong detonation wave and provide the initiating shock wave for the JP-10/air mixture. The geometry was previously determined by LT Dave Forster, USN, to provide the most rapid and reliable generation of a detonation wave in a JP-10/oxygen aerosol. The strong shock wave generated by this pilot combustor results in the direct transition of the detonation wave into the fuel/air mixture as long as the mixture is within a known detonability limit.

The atomizers used in this work produced sprays with low Sauter Mean Diameters (SMD), typically 7mm to 10mm over a wide range of flow rates, thereby allowing the spray SMD to be approximately constant through a wide range of fuel/air ratios. SMD values of the aerosol exiting the inlet arms were measured for conditions ranging from a temperature of 285K to 500K and air flow rates of 0.07 kg/s to 0.30 kg/s. By combining the measured particle size and concentration and knowing the initial amount of fuel sprayed, the amount of fuel vaporized at the point of injection into the main combustor was estimated. The results for an air flow rate of 0.20 kg/s and overall equivalence ratio of 1.5 for the JP-10/air mixture are shown below in Figure 4 for varying engine inlet temperatures. Detonations were only observed for inlet temperature above approximately 345K. The corresponding aerosols detonated therefore had SMD values below approximately 3 microns and an estimated fuel vapor above 70%. Test runs

which demonstrated a higher success rate at producing detonations were for higher inlet air temperatures and subsequently smaller droplets and fully vaporized fuel. A sample trace for one cycle of a JP-10/air detonation is shown in Figure 5 for an engine inlet temperature of 425K. The fuel was completely vaporized before initiation for this case. The pressure-time traces reveal the extremely high detonation wave velocities observed and the result head-end pressure which produces the thrust for these systems.

The successful detonations observed possessed detonation wave speeds generally within 2% of the expected Chapman-Jouget values. This result appears to indicate that although a portion of the fuel may have been in a liquid state, enough fuel vapor was present to initiate a reaction and provide rapid heating, vaporization, and reaction rates behind the shock wave to result in near Chapman-Jouget velocities.

The JP10-fueled pulse detonation engine has been operated at frequencies up to 5Hz and is in the process of being retrofitted with new fuel injectors to investigate operation at up to 100Hz. Performance parameters will be measured as a function of cycle frequency, simulated flight velocity, partial

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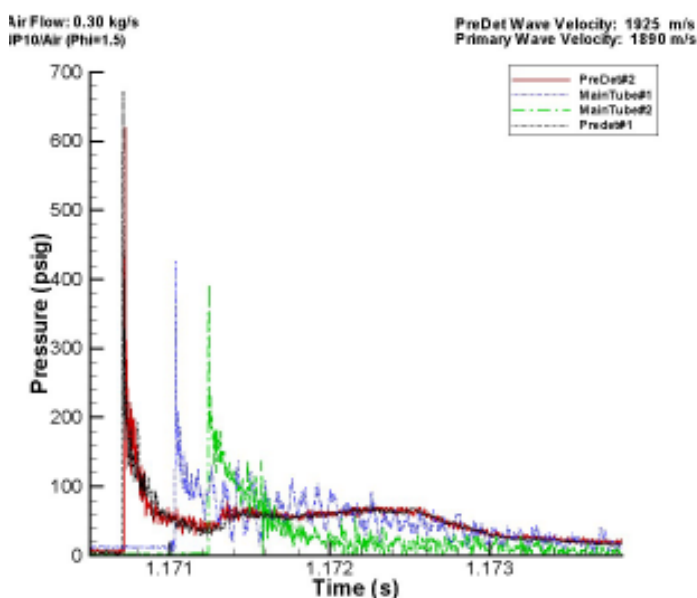
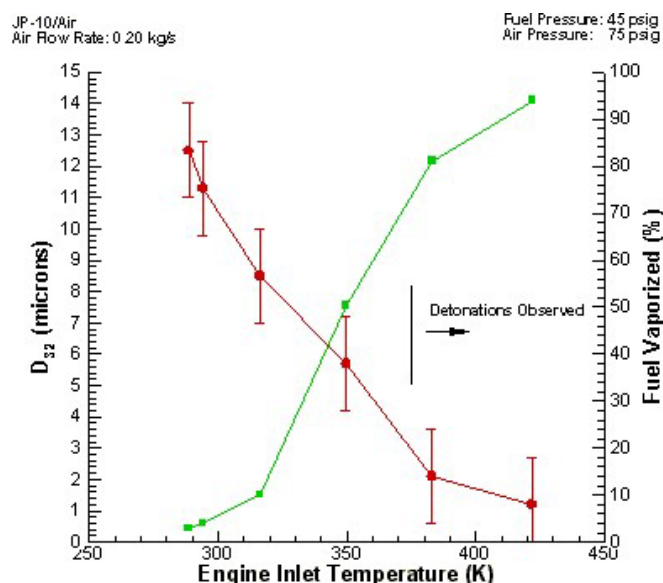


Figure 4 (left). Sauter Mean Diameter and Percent Fuel Vaporization as Function of Temperature.

Figure 5 (above). Pressure-Time Trace for JP10/Air Detonation.

## FEATURED PROJECT

### MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 9*

streaklines. The very low turbulence levels in the water tunnel minimize dye-dispersion providing excellent visualization far downstream of the test model. Flow velocity is measured using the LDV equipment described above. LDV works well in water, as the water has enough natural particulates, and no flow seeding is required. Additionally, the LDV probe is attached to a three-axis translation table for automated data acquisition.

#### Flapping-Wing Propulsion

The first explanation of the bird's ability to generate a thrust force by means of flapping its wings seems to have been published by Knoller (1909) in Vienna and Betz (1912) in Göttingen. They noted that for a slender wing, at a low incidence angle to the incoming flow, the net force on the airfoil was very nearly at a right angle (normal) to the incoming flow,

as indicated in Figure 3.

Their theory assumed that the drag on the wing was very small in comparison to the lift, which is a fair approximation in many cases. Their simplified theory, sometimes referred to as linear theory, assumes that the resultant force is normal to the incident flow.

Following this line of thought, if the airfoil is moved up or down at a fixed speed, the airfoil sees an induced vertical velocity due to this motion, which results in an incoming velocity with an incidence to the real free-stream direction, as

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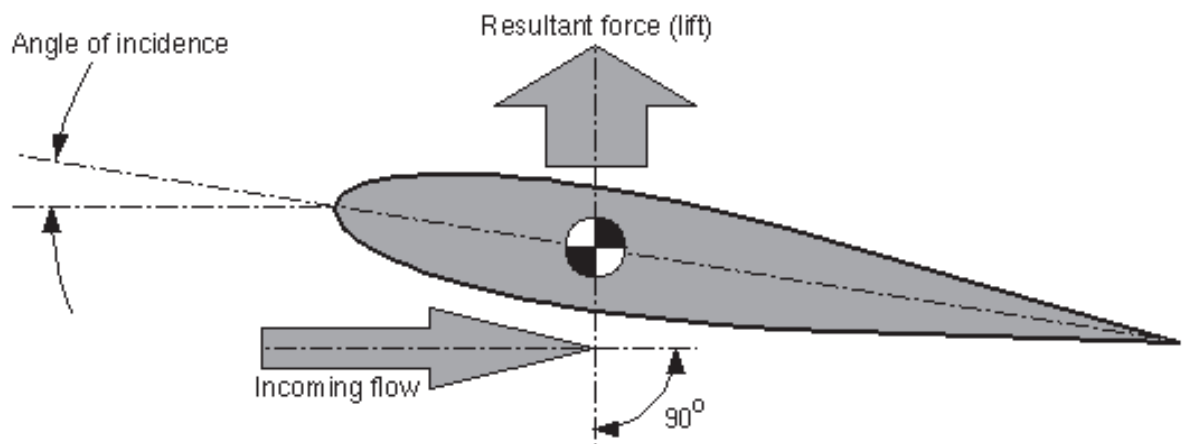


Figure 3. Normal-force vector for a wing in steady flow.

### JP-10/AEROSOL FOR PULSE DETONATION APPLICATIONS, *continued from page 41*

fuel injection, and equivalence ratio. Current work involves the imaging of JP10/air detonation waves propagating along varying sections of the engine. Framing rates as high as 150,000 frames per second will be utilized for both Schlieren and fluorescence imaging of the wave propagation at critical locations. Figure 6 shows the test section to be used.

The students involved with this work were LT Todd Hofstedt, USN, LT Robert Johnson, USN, and LT John Robinson, USN. Additional support was provided by aerospace technician Mr. Harry Conner. The sponsor for this work is the Office of Naval Research.

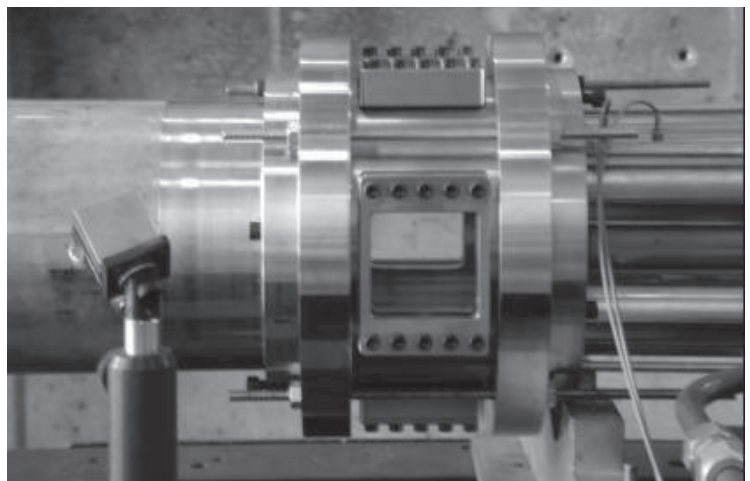


Figure 6. Optical Test Section Insert.

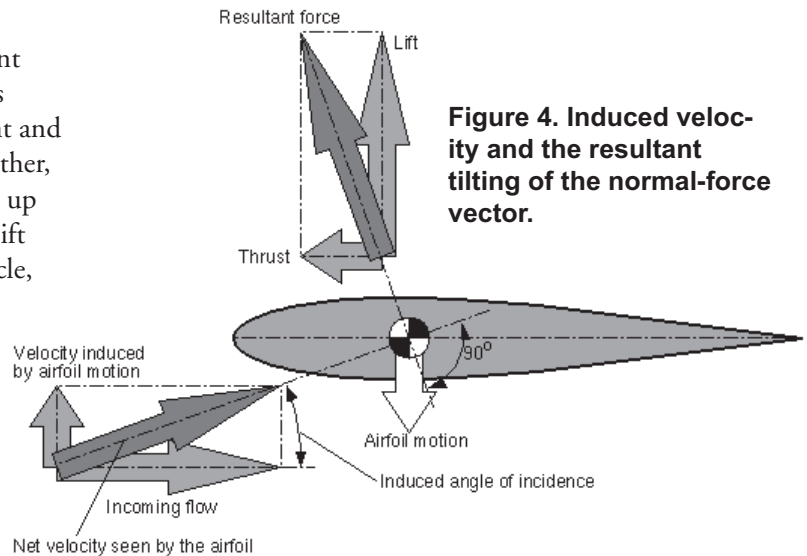
# FEATURED PROJECT

## MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 42*

shown in Figure 4.

Since the resultant force must be normal to the incident flow, the resultant force vector must be tilted forward, as shown in Figure 4, which provides both a lift component and a thrust component. Knoller and Betz went one step further, and they noted that if the wing was flapped (plunging it up and down vertically in an oscillatory fashion) while the lift force would be both positive and negative during the cycle, averaging to zero, the thrust force would always be non-negative, so the average thrust would be a positive value. (For an animated demonstration of this phenomenon, visit our online version of this article at [www.aa.nps.navy.mil/~jones/research/unsteady/propulsion/theory/](http://www.aa.nps.navy.mil/~jones/research/unsteady/propulsion/theory/)).

Prandtl's student Birnbaum (1924) first presented a solution for incompressible flow past flapping airfoils, while Katzmayr (1922) in Vienna produced the first wind tunnel measurements which conclusively showed that an airfoil mounted in an oscillating wind stream experiences a thrust force. In the 1940's and 50's Schmidt (1965) in East Germany started to conduct systematic experiments on flapping foil propellers which led him to the development of the wave propeller and its demonstration on a catamaran boat. Classical oscillatory thin airfoil theory shows that the propulsive efficiency of a single harmonically plunging airfoil is only about 50 percent unless the airfoil oscillates rather slowly (which in turn requires a large airfoil in order to obtain



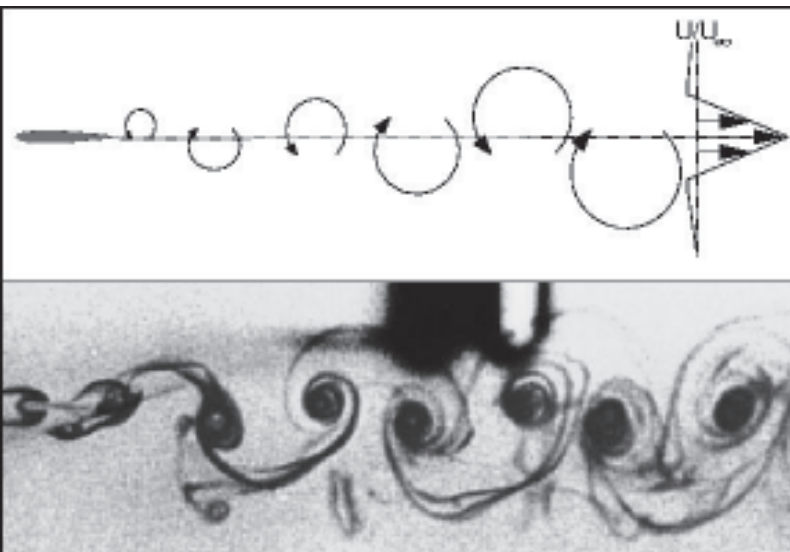
**Figure 4. Induced velocity and the resultant tilting of the normal-force vector.**

significant thrust values). Schmidt sought to overcome this deficiency by arranging two airfoils in tandem, where the forward foil is oscillating and the rear-ward foil is stationary. This makes it possible to convert the vortical energy generated by the forward foil into additional thrust rather than being wasted. Schmidt claimed that his wave propeller achieved efficiencies comparable to those of conventional propellers and had the additional advantage of enabling operation in shallow waters.

### Flapping Wings Generate Vortices

It is a well known fact that a vortex is generated whenever an airfoil changes its angle of attack. Therefore, a flapping airfoil continuously sheds vortices from its trailing edge. We have made extensive studies of this vortex shedding phenomenon. Two examples are shown in Figures 5 and 6, where the lower image is a photograph of the water-tunnel experiment, and the upper image is a schematic representation of the vortices. If one measures the time-average of the flow at some station downstream of the trailing edge (as we did using the previously described LDV instrumentation), one obtains the jet-like distribution schematically shown in the upper part of Figure 5. Hence the flapping wing generates a jet similar to the jet produced by a conventional propeller or jet engine.

It is interesting to note, however, that when we flap



**Figure 5. Thrust Indicative Vortex Street.**

*--continued on page 44*

## FEATURED PROJECT

### MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 43*

#### FURTHER READING:

Dohring, C. M., "Experimental Analysis of the Wake of an Oscillating Wing," Master's Thesis, Naval Postgraduate School, Monterey, CA, June 1996.

Dohring, C. M., Fottner, L. and Platzer, M. F., "Experimental and Numerical Investigation of Flapping Wing Propulsion and its Application for Boundary Layer Control," ASME 98-GT-46, June 1998.

Jones, K. D. and Platzer, M. F., "Numerical Computation of Flapping-Wing Propulsion and Power Extraction," AIAA Paper No. 97-0826, January 1997.

Jones, K. D., Dohring, C. M. and Platzer, M. F., "Experimental and Computational Investigation of the Knoller-Betz Effect," *AIAA Journal*, Vol. 36, No. 7, July 1998.

Jones, K. D. and Platzer, M. F., "An Experimental and Numerical Investigation of Flapping-Wing Propulsion," AIAA Paper No. 99-0995, Reno, Nevada, January 1999.

Jones, K. D., Lund, T. C. and Platzer, M. F., "Experimental and Computational Investigation of Flapping-Wing Propulsion for Micro-Air Vehicles," presented at the Conference on Fixed, Flapping and Rotary Wing Vehicles at Very Low Reynolds Numbers, Notre Dame, Indiana, June 2000.

Lai, J. C. S., Yue, J. and Platzer, M. F., "Control of Backward-Facing Step Flow Using a Flapping Airfoil," ASME FEDSM97-3307, June 1997.

Lai, J. C. S. and Platzer, M. F., "The Characteristics of a Plunging Airfoil at Zero Free Stream Velocity," ASME FEDSM98-4946, June 1998.

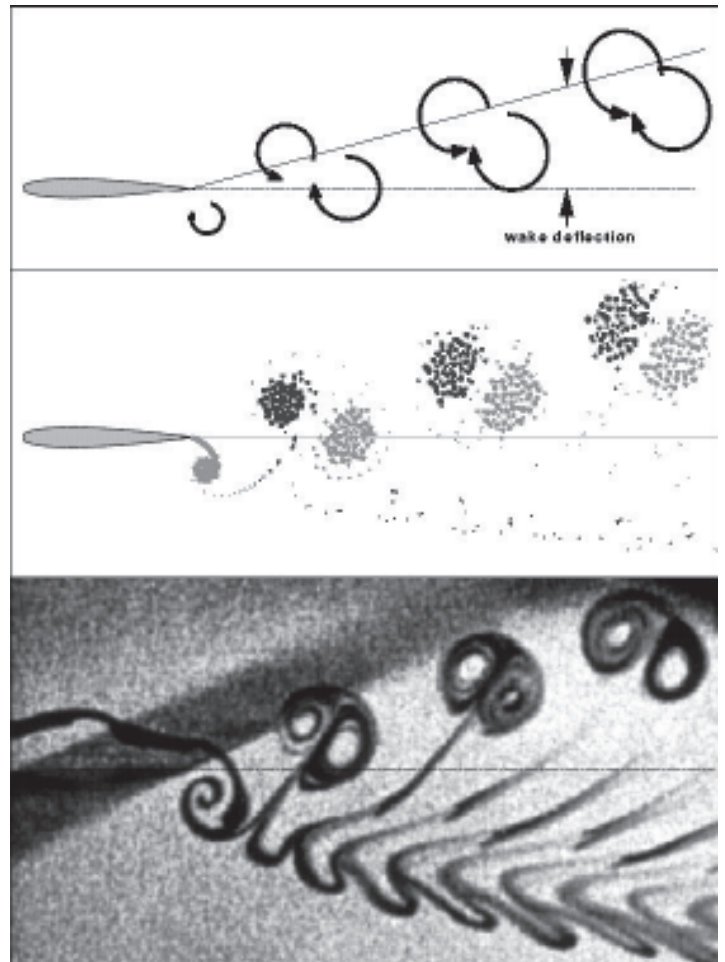
Lai, J. C. S. and Platzer, M. F., "Jet Characteristics of a Plunging Airfoil," *AIAA Journal*, Vol. 37, No. 12, December 1999, pp. 1529-1537.

Platzer, M. F., Neace, K. S. and Pang, C. K., "Aerodynamic Analysis of Flapping Wing Propulsion," AIAA Paper No. 93-0484, January 1993.

Tuncer, I. H. and Platzer, M. F., "Thrust Generation due to Airfoil Flapping," *AIAA Journal*, Vol. 34, No. 2, 1996, pp. 324-331.

Tuncer, I. H., Walz, R. and Platzer, M. F., "A Computational Study of the Dynamic Stall of a Flapping Airfoil," AIAA Paper No. 98-2519, June 1998.

Tuncer, I. H. and Platzer, M. F., "Computational Study of Flapping Airfoil Aerodynamics," *Journal of Aircraft*, Vol. 37, May-June 2000, pp. 514-520.



**Figure 6: Deflected wake comparison ( $kh=1.5$ ).**

the wing more energetically the vortices start to shed at an angle, as shown in Figure 6. In this case both thrust and lift are generated. We seem to have been the first to document this effect which we are able to reproduce both experimentally and numerically (the central image in Figure 6 is a numerical solution using a panel code we developed with several thesis students). It occurs as soon as the product of the flapping amplitude and frequency exceeds a critical value. (Visit [www.aa.nps.navy.mil/~jones/research/unsteady/propulsion/high\\_freq/](http://www.aa.nps.navy.mil/~jones/research/unsteady/propulsion/high_freq/) for an animation).

More recently, we could confirm these flow visualizations and measurements with much more accurate and time-consuming computations based on the numerical solution of the viscous flow equations, i.e., with a Navier-Stokes code.

Birds generally use a combination of pitching and plunging

*--continued on page 45*

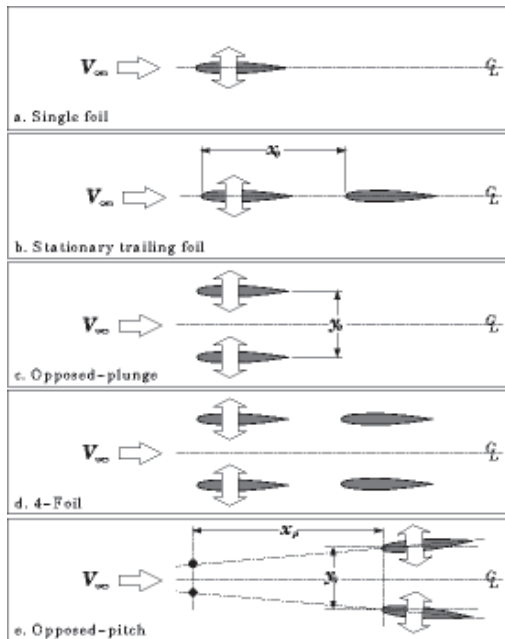
# FEATURED PROJECT

## MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 44*

motion rather than a single degree of freedom pitch or plunge motion. This expands the parameter space considerably. In addition to the pitch and plunge amplitudes one now has to consider the phase angle between the pitch and plunge motions. It is important to realize that the key parameter for determining whether an airfoil generates thrust or extracts power from a flow is the effective angle of attack, as illustrated in Figure 7. Cases (a) and (b) represent the pure plunge and pitch modes. Case (c) is the neutral case (pure feathering) between thrust generation and power extraction. A negative effective angle of attack (relative to the flight path) leads to thrust generation, case (d), a positive angle to power extraction, case (e).

### Interference Effects

As already mentioned, Schmidt (1965) sought to develop an efficient flapping foil propeller by exploiting the interference effect between a flapping fore-wing and a non-flapping hind-wing. The stationary hind-wing is exposed to an oscillatory flow and therefore can exploit the Katzmayr effect, i.e., convert the vortical energy generated by the flapping fore-wing into additional thrust.



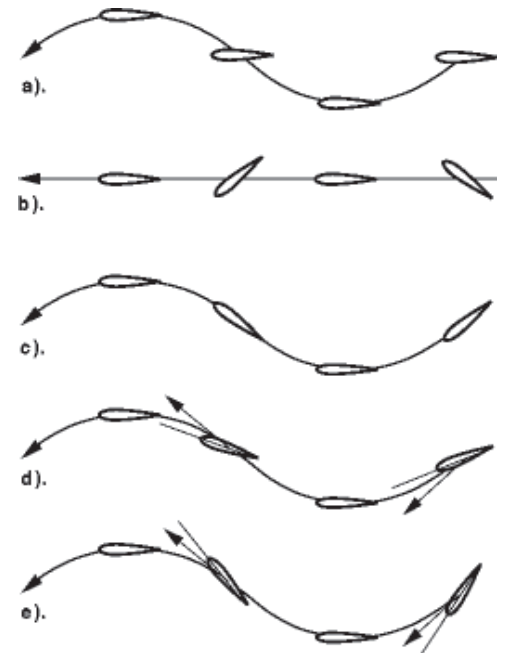
**Figure 8: Numerical and experimental configurations.**

either a pure plunge mode or a combined pitch/plunge mode with the optional mounting of two stationary hind-wings as shown in Figure 8d.

### The Flapping-Wing Micro-Air Vehicle

As a result of the experimental and computational investigations performed on the tandem configuration (Figure 8b) and the biplane configuration (Figure 8c), we have concluded that the latter configuration is the most promising one. Therefore, we have adopted the modification, shown in Figure 8e, for mechanical

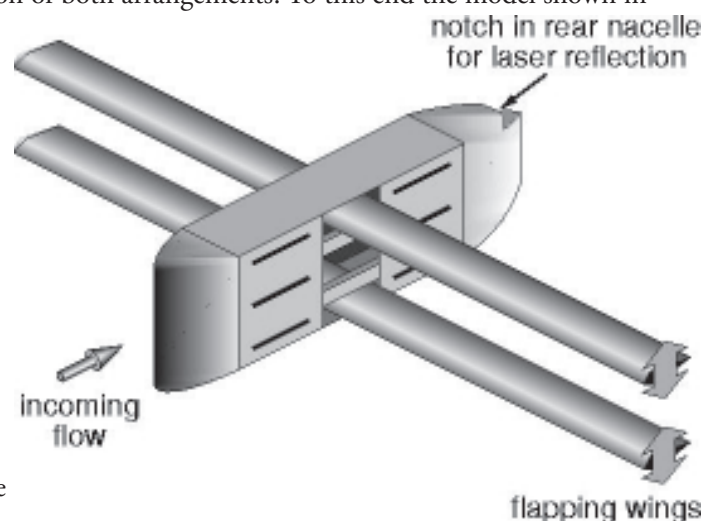
*--continued on page 46*



**Figure 7: Effective versus geometric AoA.**

Two arrangements are of greatest interest, namely the tandem and the biplane arrangement, shown as Figures 8b and 8c, respectively. Visit [www.aa.nps.navy.mil/~jones/research/unsteady/panel\\_methods/anim3/](http://www.aa.nps.navy.mil/~jones/research/unsteady/panel_methods/anim3/) and [www.aa.nps.navy.mil/~jones/research/unsteady/panel\\_methods/anim2/](http://www.aa.nps.navy.mil/~jones/research/unsteady/panel_methods/anim2/) to see animated simulations of these configurations.

The latter arrangement is equivalent to a single airfoil oscillating in ground effect provided the oscillation of the two airfoils in the biplane arrangement occurs in counter-phase. We performed a detailed computational and experimental investigation of both arrangements. To this end the model shown in Figure 9 was built and tested which allowed the flapping of the two fore-wings in



**Figure 9: Isometric view of the large model.**

## FEATURED PROJECT

### MICRO-AIR VEHICLE AERODYNAMICS, *continued from page 45*

simplicity, and we have built the six gram micro-air vehicle shown in Figure 10. This model is presently undergoing extensive testing to better understand the low Reynolds number, unsteady aerodynamic characteristics and to accurately measure thrust.

#### Boundary Layer Propulsion and Flow Separation Control

As already mentioned, a flapping foil is a device which generates a jet flow downstream of the trailing edge and imparts additional momentum to the flow. Hence the question arises whether small flapping foils can be used to energize a boundary-layer flow or to prevent/delay flow separation. Therefore, we have performed several experiments to explore the flow physics of foils flapping in a boundary layer or in a separated flow region.

Flow visualization studies, LDV measurements and Navier-Stokes computations were performed to determine the flow characteristics generated by a small foil which executes a sinusoidal plunge motion in a flat-plate boundary layer. It was found that the jet velocity generated downstream of the plunging foil increases with decreasing distance from the flat plate. The plunge amplitude, frequency and distance from the wall were varied quite systematically and it was found that there is an optimum spacing between plate and foil. The jet velocity could be almost doubled compared to the values measured in a free-stream. This finding is quite consistent with the previously mentioned favorable biplane interference effect where the two foils oscillate in counter-phase, simulating the ground effect. In a second experiment, a small plunging airfoil was mounted in the separated wake flow region of an airfoil which had a semi-circular or a cusped trailing edge. Complete flow re-attachment could be achieved by selecting the proper plunge amplitude and frequency. In a third experiment, the sinusoidally plunging foil was mounted in the recirculatory flow region caused by the flow over a backward-facing step. The extent of the separated flow region

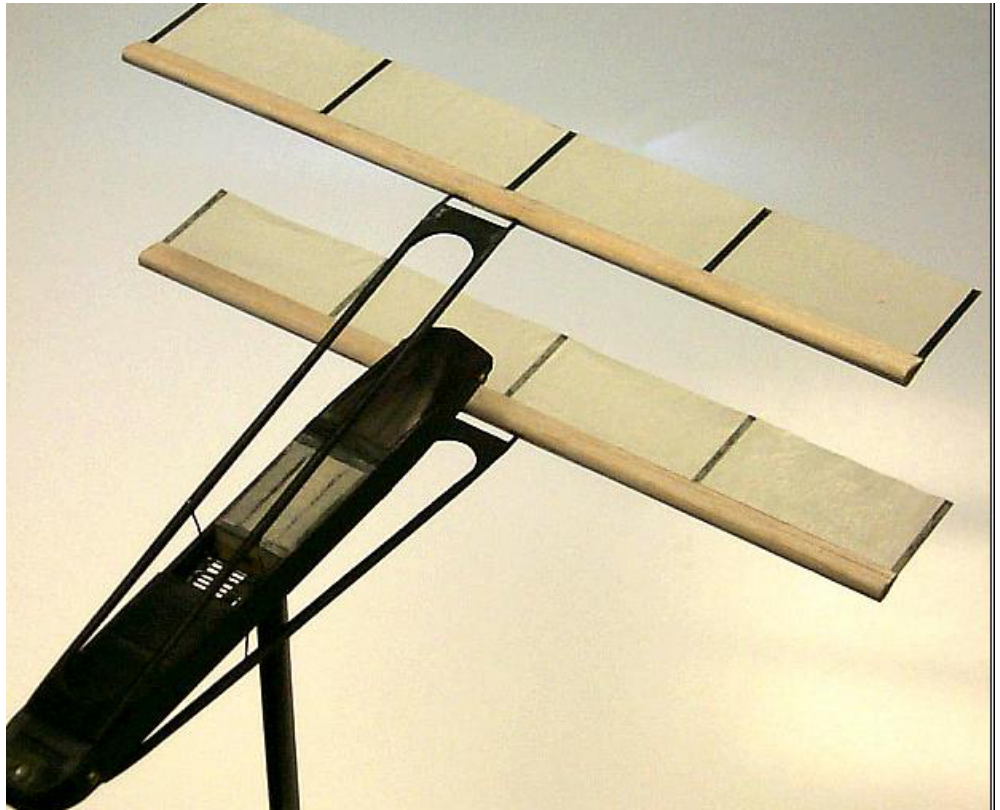


Figure 10: The six gram MAV test model.

could be reduced by more than 60 percent by proper placement, frequency, and amplitude of the plunging foil. Finally, in a fourth series of experiments a small plunging foil was placed in the wake of a conventional airfoil. We could show that the velocity defect in the wake could be substantially reduced, making the wake almost indistinguishable from the free-stream flow.

#### Summary

We hope to have shown that the aerodynamics of flapping wings pose many as-yet unanswered questions regarding the complicated, unsteady flowfields, especially in the low Reynolds number regime. The design of successful micro-air vehicles is hampered by an insufficient understanding of the flow physics at very low Reynolds numbers. The challenges confronting the designer of micro-air vehicles are similar to those encountered in the early days of aviation, thus making it an exciting new frontier in aeronautical engineering. Interested readers can find further details in the papers listed below or by visiting [www.aa.nps.navy.mil/programs/aero/](http://www.aa.nps.navy.mil/programs/aero/) and [www.aa.nps.navy.mil/~jones/research/unsteady/](http://www.aa.nps.navy.mil/~jones/research/unsteady/).

# RESEARCH AND EDUCATION

## WEAPONEERING: FROM A JTCCG/ME PERSPECTIVE, *continued from page 13*

over the last 10 months a set of notes to hand out to the students. If the necessary clearances can be obtained, these notes will form the basis of the first textbook in weaponeering. The course is unique, certainly in the U.S. and maybe outside. Considerable interest in the material has been expressed by many of the people who are colleagues in the JTCCG community, who like Driels would like to understand “the bigger picture” as well as their own area of speciality. The course may be offered as a short course outside NPS in the future.

Working in this more operationally oriented environment is very different from that associated with a more traditional academic research program. The latter is usually associated with producing as an end product peer reviewed journal papers, conference papers, reviews of other peoples papers and so on. In the JTCCG, there is an Operational Users Working Group (OUWG) which meets twice a year at bases all over the U.S. At these meetings, the audience is comprised of around 50 aviators, planners, targeteers, military and civilian users of JAWS. The researchers present their accomplishments over the last six months and outline their plans for the next six. The aviators are not slow in coming forward to say what they think of your work after all, they may be using it in the next month to go into harms



**Figure 4. JTCCG Operational User Working Group Meeting at Dyess AFB.**

way. This gives an immediacy that was absent from more traditional programs, and an overriding motive to “get it right the first time.” Debugging one’s code by losing a few FA-18s is expensive! Participants from a recent meeting of the

*--continued on page 48*

## ME4300 WEAPONEERING – COURSE SYLLABUS, *continued from page 13*

- 9.3 Fractional overlap of target by damage function
- 9.4 Target smaller than the damage function
- 9.5 Spreadsheet implementation

### 10. Stick deliveries

- 10.1 Introduction
- 10.2 Weapon release conditions
- 10.3 Calculating stick length
- 10.4 Ballistic dispersion for sticks
- 10.5 Pattern dimensions
- 10.6 Weapon sparsity and overlap in the pattern
- 10.7 Computing SSPDs
- 10.8 Spreadsheet implementation

### 11. Projectiles

- 11.1 Guns
- 11.2 Rockets
- 11.3 Spreadsheet implementation

### 12. Cluster munitions

- 12.1 Releasable dispensers
- 12.2 Time and altitude fuzing
- 12.3 Trajectory computations for cluster munitions
- 12.4 Wind corrected munitions dispenser (WCMDs)
- 12.5 Spreadsheet implementation

### 13. Methods for particular types of target

- 13.1 Buildings
- 13.2 Bridges
- 13.3 Linear targets (runways, railroad tracks etc.)
- 13.4 Hardened targets
- 13.5 Ships

### 14. Methods for particular types of weapon

- 14.1 GPS guided munitions
- 14.2 Conventional air launched cruise missiles (CALCM)

## RESEARCH AND EDUCATION

### WEAPONNEERING: FROM A JTTCG/ME PERSPECTIVE, *continued from page 47*

OUWG at Dyess ABF in Abilene Texas are shown in Figure 4.

Another unexpected benefit of working directly with JAWS users is the ability to experience their environment directly. For example, when developing the target acquisition program shown in Figure 2, the pilots and WSOs would be questioned about what a target looks like on a FLIR compared to a radar, or how difficult it is to place targeting crosshairs on a radar screen. They would try to answer as best they could, but the usual response was that Driels should fly in the aircraft and see it firsthand. This proved more difficult than Driels thought, but with the support of the Superintendent, he received the three day water survival and aviation physiology training at NAS Lemoore enabling him to fly



**Figure 5. B-52 Weapons School.**

backseat in military aircraft. This has been of great benefit in understanding not just the theory of the subject, but the application also. Figure 5 shows participants of one such mission about to depart from Barksdale AFB with the USAF B-52 Weapons School, on a series of low-level bombing runs over the Utah test range. In this mission, JAWS was used extensively, and provided the opportunity to obtain field data for direct comparison with the predicted outcome of the mission. It is hard to imagine getting better data anywhere in the academic world.

Another weaponneering scenario of interest to the Navy is the application of Mk 20 cluster munitions against small boats. In one such study, Driels was able to observe first hand the tactics used by flying with VS-35 from NAS North Island San Diego (Figure 6).



**Figure 6. Flying S-3 aircraft with VS-35.**

# RESEARCH CENTER

## RAD-HARD SEMICONDUCTOR CHIPS, *continued from page 17*

Berkeley, University of Michigan and Vanderbilt and national laboratories such as; NRL, AFRL, NRAD, JPL, NSWC-Crane and Draper. Over the last 10 years more than 100 NPS student theses have been related to radiation effects in electronics. Some students return to the organizations that require knowledge on radiation effects which provide close ties with NPS. Much of the student thesis research interacts with the engineering duty organizations such as U.S. Navy Strategic Programs, National Reconnaissance Office and the Space and Naval Warfare Systems Command.

### Present and Recent NPS Radiation Effect Research Projects

- 1995 – 1999: NPS faculty lead a program with NRL, UC

Berkeley, Motorola, Honeywell and others to develop semiconductor wafers for high performance GaAs ICs that could substitute the unhardened bulk GaAs wafer. The reengineered wafer is transparent to the manufacturing process, and provides radiation immunity. (Weatherford/Fouts)

- 1997 – Present: Work has been performed in conjunction with the University of Michigan's Center for Ultrafast Science to measure picosecond / nanovolt resolution signals internal to the chip. A 100 femtosecond pulsed laser is used to simulate a "soft error" and provide optical sampling to resolve electrical signals. This collaboration

*--continued on page 50*

## THE "LINAC", *continued from page 17*

Figure 2 is a view of the accelerator taken from the electron gun end. Figure 3 shows the power klystrons and Figure 4 shows the inside of the high voltage supply for the klystrons, which is also called the modulator.

### Early Research Areas

The main interest of Franz Bumiller concerned the structure of deuterium and the neutron. This was investigated by measuring the angular distribution of electrons scattered by the deuterium target. These measurements yielded information about the distribution of charge in the neutron that is probably still valid today.

Later nuclear experiments with R. Pittham from Darmstadt, Germany and collaborators discovered experimentally the electric quadrupole collective oscillation of medium to heavy nuclei, as predicted by A. Bohr. These experiments were

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Figure 2 (above). A view of the "beamline."

Figure 3 (right). Three high power klystrons deliver power to one ten foot accelerator section.

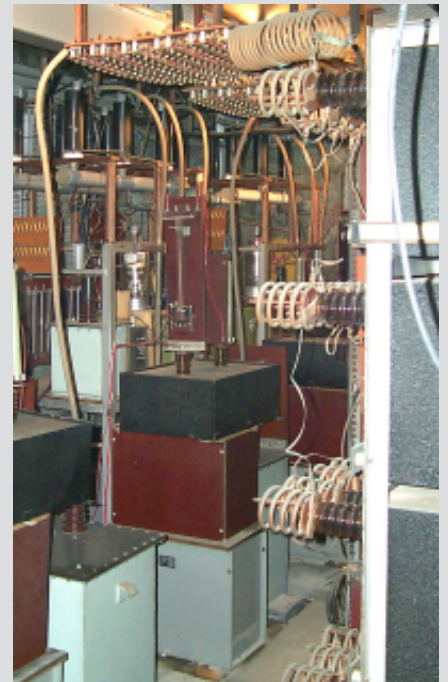


Figure 4 (above). High voltage supply for the klystrons, which is also called the modulator.

## RESEARCH CENTER

### RAD-HARD SEMICONDUCTOR CHIPS, *continued from page 49*

was the first to measure in-situ and characterized “soft errors” during the operation of a 20 GHz circuit. The technique was first shown with Hughes’ digital InGaAs Heterojunction Bipolar technology and additional work continues with AFRL, MIT-LL and SPAWAR. (Weatherford/Fouts)

- 1998 – Present: NPS has a unique relationship with Silvaco International, a Santa Clara firm that develops “Virtual Fab” software. We have the capability to simulate the IC fabrication process, electrically characterize it, and irradiate the “virtual device” in software to understand effects. It is also faster and safer than designing and performing experiments, however experiments are required to verify the computer models. Further simulation analysis can study new transistor structures or materials to increase radiation hardness. Present work supports the SPAWAR San Diego Silicon-on-Insulator Foundry, with cooperation from Dynamic Research Corporation, and Vanderbilt University. (Weatherford)
- 1999 – Present: Projects with Draper Labs to study displacement damage in photodetectors for the Trident program. (Weatherford)
- 1999 – Present: Projects with NSWC Crane to investigate radiation susceptibility of new generation rad-hard power transistors (Ciezki/Ashton)
- 1994 – 99: Projects with NRL, SPAWAR to design low-power logic families in GaAs IC technologies for rad-hard environments. Professor Fouts received a patent on his

inventions in this area. (Fouts)

- 1997 – Present: Study and analysis of silicon based CMOS technologies for total dose radiation effects for proprietary NSA integrated circuits. This work has led to new IC layout procedures and has been extended into a software tool with Lockheed-Martin to design integrated circuits for weapon environments. (Fouts)
- 1995-Present – Modeling and analysis of InP, GaAs and Si solar cells for space applications, supported by both AFRL and NRL in investigating degradation in solar cells and in operational amplifiers. (Michael)

Shown above are only a few research projects, many opportunities exist in this field, from the design of rad-hard circuits and systems, analysis and testing of components for present systems, to the future modeling of next generation semiconductor technologies. The organization of a multidisciplinary center at NPS in areas of electrical engineering, space systems, materials engineering, and physics to support DoD in this critical technology area should help focus continued and new support from outside the NPS while providing an important service to the strategic and space communities.

Just remember next time you get upset at your laptop hanging up in a cross-country flight, or your new 1 GHz high performance desktop gets hungup, you may need to buy some rad-hard chips, not reinstall Windows®. Hopefully our future defense systems designers will be able to acquire rad-hard parts in the future.

### THE “LINAC,” *continued from page 49*

extended to other heavy nuclei as far as lead and uranium.

Almost from the beginning, the effects of radiation was investigated on various systems as diverse as semiconductors, polymers, and later, the recently discovered high temperature superconductors. The investigations of semi-conductors and devices were aimed at measuring the radiation levels causing degradation, to anticipate effects of either space radiation or nuclear detonations. The unexpected result for some high temperature superconductors was an actual enhancement of some properties after irradiation.

The electron beam from the LINAC may be used to produce electromagnetic waves by various distinct mechanisms. Transition radiation occurs when the electrons pass a boundary, such as a metal or plastic foil, and this radiation occurs in the radio frequency optical and x-ray regions.

Experiments here were aimed at soft x-ray productions from single and multiple foils.

Cerenkov radiation occurs if the electrons exceed the speed of light that can only occur in a medium even air. Coherent Cerenkov radiation was observed in which the many electrons in a bunch generated by the LINAC radiate together and reinforce.

Another phenomenon called parametric x-rays (PxR) was measured. Here x-rays are produced when the electron passes through a crystal. Typical crystal spacings result in 5 to 10 kilovolt x-rays.

Over the years the facility has been used for various projects, and oddly enough in recent years the research is going back to its roots, studying radiation effects in semiconductors for strategic systems.

# CONFERENCE CALENDAR

## CONFERENCES/MEETINGS AT THE NAVAL POSTGRADUATE SCHOOL

<u>Dates</u>	<u>Title</u>	<u>Sponsor</u>
4-6 Oct 00	Thermobaric Processes in the Weddell Sea	Naval Postgraduate School
25-26 Oct 00	Counter-Precision Guided Munitions Conference	Joint Staff (J-39), Secretary of the Air Force, US Army Materiel Command, Office of Naval Research
31 Oct - 2 Nov 00	2000 Information Warfare Workshop	Department of Energy and Office of Energy Intelligence
31 Oct - 3 Nov 00	Military Librarians Workshop 2000	Military Librarians Division of the Special Libraries Association
7-10 Nov 00	AIAA 2000 Missile Sciences Conference	American Institute of Aeronautics and Astronautics
13-16 Nov 00	Aircraft Survivability 2000 Science and Technology Initiatives Symposium	Air Force Research Lab
30 Nov - 8 Dec 00	Army TENCAP Users Working Group	Army Space Program Office
29 Jan - 1 Feb 01	Military Sensing Symposia (MSS) Specialty Group Meeting on Missile Defense Sensors, Environments and Algorithms	US Army Communications Electronics Command
19-23 Mar 01	17 <sup>th</sup> Annual Review of Progress in Applied Computational Electromagnetics	NPS, Applied Computational Electromagnetics Society
27-29 Mar 01	12 <sup>th</sup> Annual TACOM Ground Vehicle Survivability Symposium	US Army Tank-Automotive and Armaments Command
22-23 Jun 01	36 <sup>th</sup> Annual Colonel Allyn D. Burke Memorial Dental Symposium	Colonel Allyn D. Burke Memorial Dental Study Club

NPS has excellent facilities for hosting conferences, workshops, symposia, and meetings. The wide range of facilities can accommodate both small and large groups. Additional rooms are available for smaller functions or breakout sessions. Conferences classified through SECRET can be accommodated on the NPS campus. Sensitive Compartmented Information Facility (SCIF) facilities exist and may be available for small groups on a more restricted basis. For more information, contact the NPS Conference Coordinator, Eileen Hamilton, at 831-656-2426 or by e-mail, [eehamilt@nps.navy.mil](mailto:eehamilt@nps.navy.mil).

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